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Meditation
A closer look at the dark side of mindfulness

Armageddon
Will an asteroid stop the US elections?

Tea
A scientist's guide to the perfect brew

Thank you, Sylvia

Sylvia left a gift in her Will to help conquer Stroke

The first we knew of Sylvia was when we received notification of the gift she'd left us in her Will. Shortly after, a beautiful story of a much-loved woman began to unfurl.

Friends remembered Sylvia's kind-heart and her wish to help others. She spent part of her adult-life caring for her mother, and developed a passion for medicine. Becoming a medical secretary was her next step and, in the course of her career, she discovered the devastating impact a stroke could have on people and their families. She saw that research and treatment were vastly under-funded, and she decided to remember the Stroke Association in her Will.

Sylvia's gift has helped fund our work to conquer stroke. She's supported research to prevent and treat stroke, and she's helped care for survivors. And that's something you can do too – in the same way.

If you would like to learn more about remembering the Stroke Association in your Will, please get in touch.

Call 020 75661505 email legacy@stroke.org.uk or visit stroke.org.uk/legacy

Stroke association

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FROM THE EDITOR

This month, we're taking a close look at the idea of mental resilience. It was an idea inspired by a conversation I had with Prof Richard Wiseman on our podcast (go and subscribe!). We were discussing luck. Earlier in his career, Richard invited thousands of people who considered themselves lucky or unlucky to his lab. Over the course of a decade, he and his team studied these people closely. Of course, they found that there was nothing magical about the 'lucky' individuals, but there was something different about how these people saw the world. It seemed they had a different set of psychological processes shaping their perception and the way they made decisions. In a sense, these people made their own luck.

As well as creating better opportunities for themselves, these 'lucky' people were more resilient. They had skills that helped them to deal with what life threw at them, skills that could be taught to others. So Wiseman set up Luck School, and it worked: no one won the lottery, but the 'unlucky' people were given the psychological tools to deal with the stress and anxiety we all encounter at one time or another, and were generally happier as a result.

So it begs the question – why aren't life skills like this taught in school? Changing your life or learning to deal with stress shouldn't just be the reserve of self-help books, often touted by those relying on first-hand experience rather than scientific evidence. With that in mind and with uncertain times ahead, we asked our writers investigate the latest research around mental resilience and how to cultivate it (p70).

Daniel Bennett

Daniel Bennett, Editor

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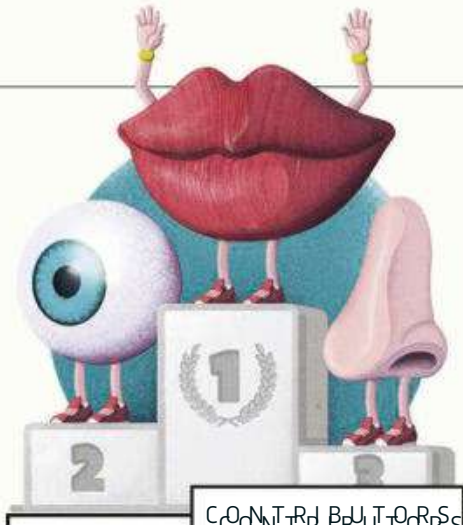

Which of our senses evolved first? → p79

CONTRIBUTORS

JULES HOWARD

Science writer Jules so enjoyed writing about slime moulds that he subsequently bought one as a pet. Discover their squidgy charms for yourself. →p52

VERITY BURNS

Verity has been tuning home cinema setups and testing hi-fis for over a decade. She takes us through the latest soundbars you can use to give your TV an upgrade. →p40

DR MIGUEL FARIAS

Meditation is huge business these days, but does it work for everyone? Miguel's review of research suggests that for some it could actually be harmful. →p34

AMY FLEMING

Heart rate variability (HRV) can reveal if you're at your most resilient or succumbing to stress. Health writer Amy finds out more about this metric. →p64

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ON THE BBC THIS MONTH...

The Touch Test
Psychologist and *All In The Mind* presenter Claudia Hammond reveals the results of the Touch Test, a questionnaire put to the British public exploring people's changing attitudes towards touch.
BBC Radio 4, 5 October

Why Do Some Planets Spin?
Could Earth be flung off-balance? Why do we only ever see one side of the Moon? The *CrowdScience* team reveals the answers to listeners' cosmic questions.
BBC World Service, 9 October, 8:30pm

Mountain Vets
The vets of Mourne mountains – the idyllic rural area in the east of Northern Ireland, where animals outnumber citizens 10 to 1 – return to our screens this month with six new episodes.
BBC Two, Fridays at 8:30pm

COVER: MAGIC TORCH THIS PAGE: BBC, GETTY IMAGES X2

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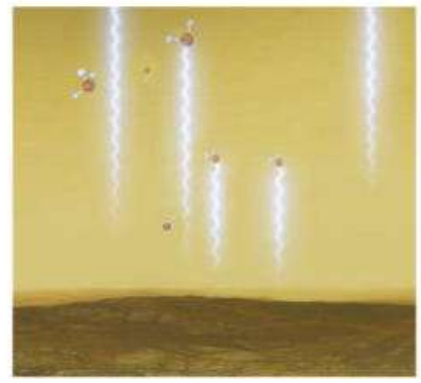

Scientists have discovered phosphine in the atmosphere of Venus – but what does this mean?

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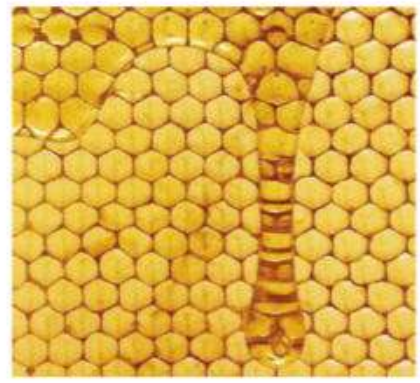

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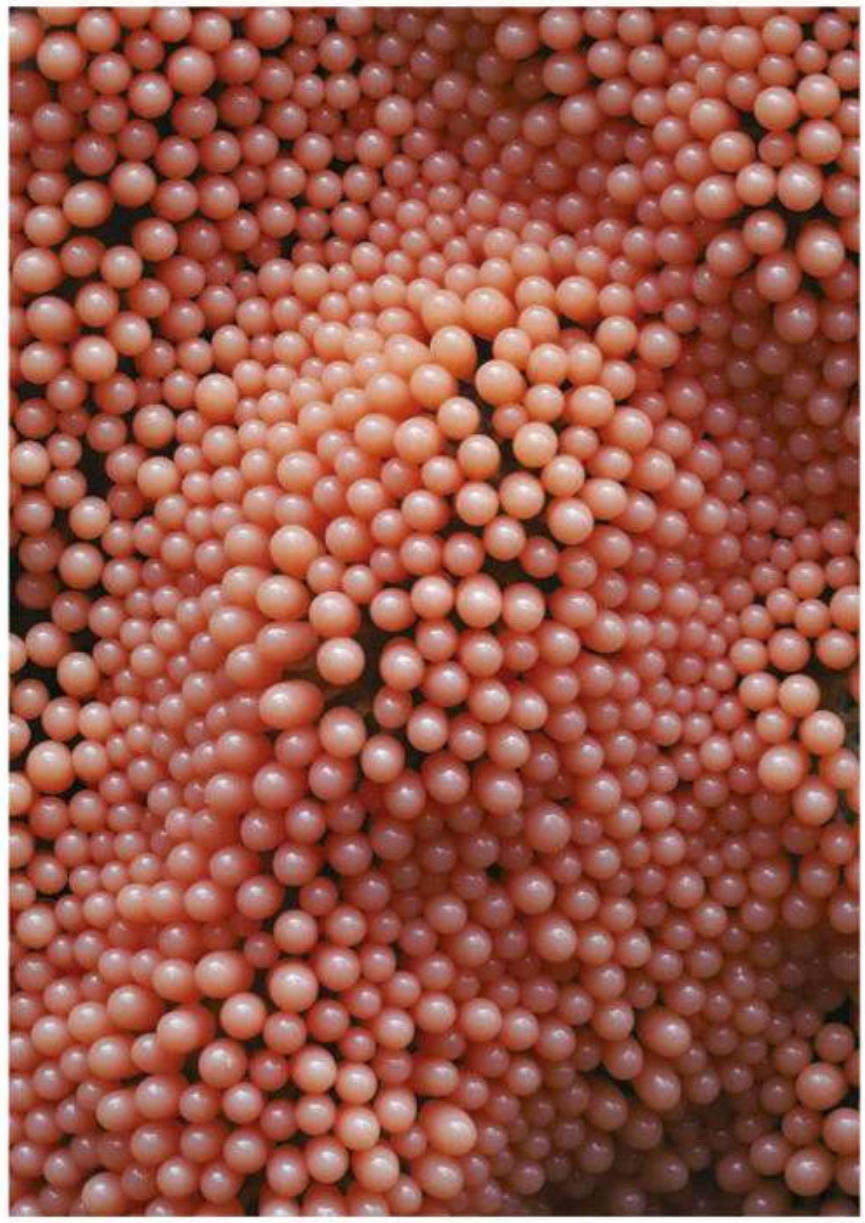

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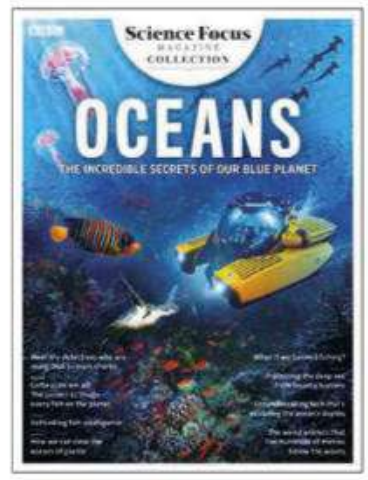
SPECIAL ISSUE



OCEANS: THE INCREDIBLE SECRETS OF OUR BLUE PLANET
In this special edition, the experts from *BBC Science Focus* don their diving kit and take the plunge into the depths of the oceans, to reveal more about the incredible world beneath the waves.
buysubscriptions.com/focuscollection

EYE OPENER

Toxic beauty

HUELVA, SPAIN

No, this isn't an extreme close-up of a leaf. It's a toxic, radioactive pond filled with industrial waste in Huelva, southern Spain. The patterns are caused by crystallisation of phosphogypsum, a radioactive by-product of manufacturing fertilisers. For over 40 years, these marshes were used as a dumping ground for 120 million tonnes of the stuff, and it's the largest landfill of its kind in Europe. But the dams that prevent the toxic residue from swamping the town are leaking. "The dams leak around 7.8 tonnes of arsenic and 1.8 tonnes of cadmium per year into the Rio Tinto river," says geochemist Dr Rafael Perez-Lopez. It doesn't help that the dams are built over swamps, so the race is on to stabilise them.

Proposals to treat the site include 'capping' the dam with a layer of earth, and even recycling the phosphogypsum waste.

MILAN RADISICS/NATUREPL.COM

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EYE OPENER

EYE OPENER

Face to face

YAMAGUCHI, JAPAN

These two male *Zoarchias major* eelpouts are evenly matched. They're locked in a protracted, intense battle, although what they're fighting about is a mystery. "My guess is it's a combination of territorial disputes and competition for mating rights," says photographer and naturalist, Tony Wu.

Little is known about these marine dwellers, although it's likely that the size of their mouth, and perhaps the markings inside their mouth, has some significance in establishing dominance. But it's not just the males who like to pick fights; females appear to be just as antagonistic. And the fighting is not confined within genders, either. "There were fights breaking out between males and females, too. These fish didn't appear to discriminate between rivals. I have not been able to find any scientific explanation, it's entirely possible it hasn't been documented before," Wu says.

TONY WU/NATUREPL.COM

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CONVERSATION

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND *BBC SCIENCE FOCUS*

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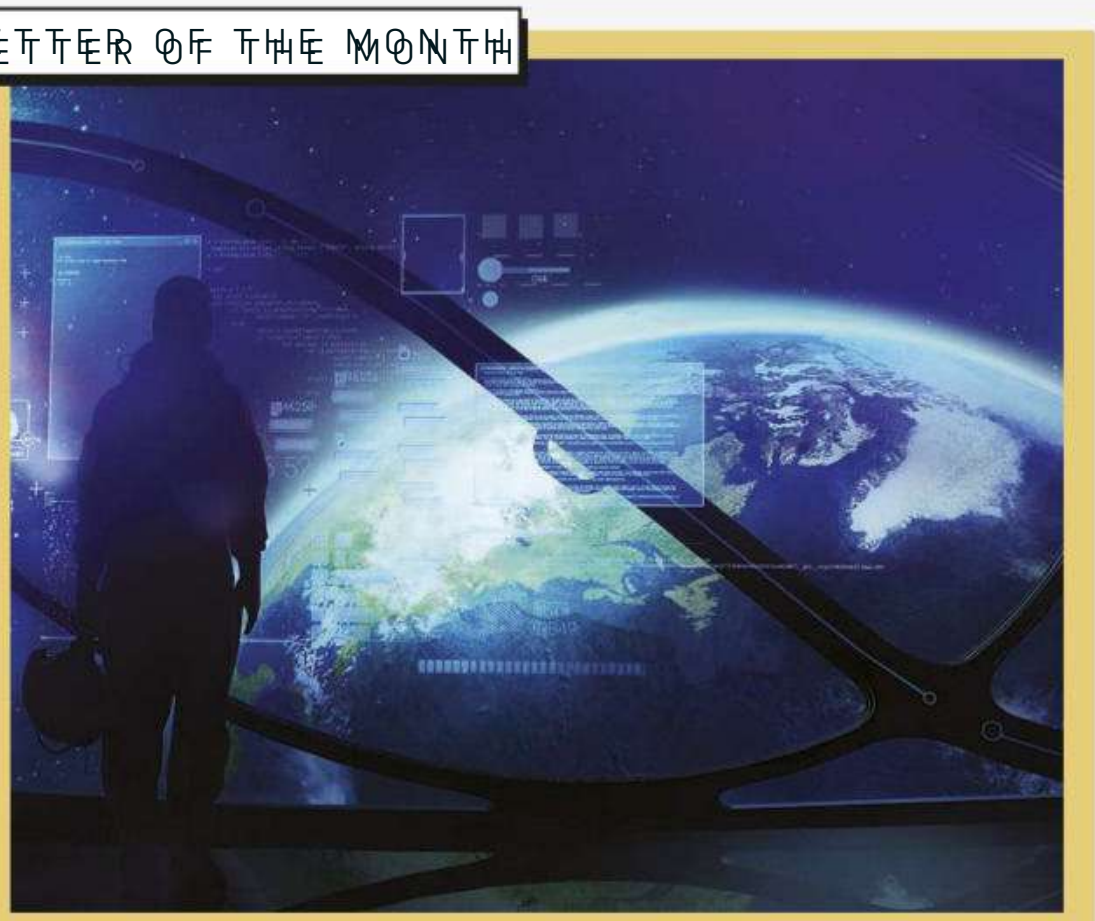
LETTER OF THE MONTH



Dear descendant...

After reading your article on faster-than-light travel (July, p33), it got me thinking about how when we look at distant, potentially habitable planets we are looking at them thousands of years in the past. Therefore, if humans eventually travel many light-years away from Earth and then look back, they will see Earth as it was in the past. Does this mean that, right now, there could be future humans looking down on us and watching me eat my porridge?!

I imagine they would also study and record us – which could end up being a future beamed-into-the-brain VR series for people to eat popcorn to.

I don't know about you, but I'm staying inside for a bit longer to avoid our voyeuristic descendants!

Martyn Kilbryde

WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins a **Marshall Emberton speaker**. This compact, portable Bluetooth speaker will give you 20 hours of play on a single charge, and a 360° listening experience. Weighing less than a kiiogram, the Emberton has a durable design and an IPX-7 water-resistant rating to boot, all wrapped up in the signature Marshall style.

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Rooster tooter

In response to a reader's question 'Do birds fart?' (**bit.ly/birds-fart**) Charlotte Corney wrote that there is no known evidence of birds farting. Obviously, chicken owners weren't included in the research. Our chickens fart a lot, sometimes wet, sometimes dry. Either way they are not subtle in sound nor smell!

William Cowan

Cycle fast

Dr Michael Mosley has previously written of the benefits of time-restricted eating (TRE). I've been on a TRE regime for some time now, giving myself a four-hour eating window per day.

Next year I'll be cycling from Land's End to John o'Groats, and I'm wondering if there have been any studies done on TRE and endurance events like this? I know the general advice seems to be a steady intake of food (for example, a banana every 30 minutes) but I wondered if there was a different (and better) way with TRE?

Ben, *via email*

"SLIME MOULDS ILLUSTRATE THAT SIMPLE ORGANISMS CAN EXHIBIT BEHAVIOURS USUALLY ENCOUNTERED IN ANIMALS WITH BRAINS. THEY ENCOURAGE US TO TAKE ANOTHER LOOK AT SINGLE-CELLED ORGANISMS" DR AUDREY DUSSUTOUR, p52

There have not been a huge number of studies on this. One review article looked at the impact of Ramadan intermittent fasting on athletic performance, and concludes that "athletes who maintain their total energy and macronutrient intake, training load, body composition, and sleep length and quality are unlikely to suffer any substantial decrements in performance during Ramadan."
Dr Michael Mosley, BBC Science Focus *columnist*

The (Martian) origin of species

Mars lost its magnetic field, and solar winds stripped it of its atmosphere four billion years ago (August, p80). This is around the time that microorganisms started growing on Earth. Is this a coincidence, or could the first life forms on Earth have been 'blown' here from Mars? Are we all actually Martians?
Mark Belbin, *Wiltshire*

'Panspermia' is the idea that life on Earth was 'seeded' by microorganisms from elsewhere in the cosmos, carried here by asteroids and comets. Mars is an unlikely source, though – the solar winds would quite rapidly kill off any resident organisms, without a magnetic field to protect them.
Sara Rigby, *online assistant,* BBC Science Focus

Eco-anxiety

Much as I appreciated your comprehensive coverage of climate change (July, p86) I believe that in answering the question 'How bad will it get?' the author avoided what is, I believe, the scientific community's consensus view – if we continue on our present path, climate change will lead to an Earth not able to support human life. Okay, she skipped around the issue by saying that "plant and animal species will be driven to extinction", but for some reason fell short of the blatant truth that we will go along with other animals. As a sufferer of eco-anxiety and a supporter of Extinction Rebellion, I believe that facing up to the truth, although painful, spurs me into action. This is a view endorsed by Caroline Hickman of the Climate Psychology Alliance, who says that by acknowledging our eco-anxiety as a mature, rational and necessary response to the environmental crisis we face, we will be able to bring about changes in our lives and join others in taking action.
Eileen Peck, *Essex*

Be rid of memorials

Reading the article on the de-naming of UCL's Galton Lecture Theatre (Summer, p34) made me wonder if there should be any memorials at all. For example, not only did the science of Albert Einstein make the atomic bomb a possibility, but he even wrote a letter to President Roosevelt urging him to develop the weapon of mass destruction, which was used twice on Japan. Perhaps we should remove all memorials to Einstein because he enabled the deaths of about 150,000 Japanese people?

There will probably always be some flaw in anyone's personal history, if only realised long after the person's death. Perhaps people in the future will consider today's practices of eating meat or using fossil fuels to be unforgivable, which will produce a long list of flawed people. So, I think it's probably best to have no memorials at all.
John Bradbury, *Norfolk*

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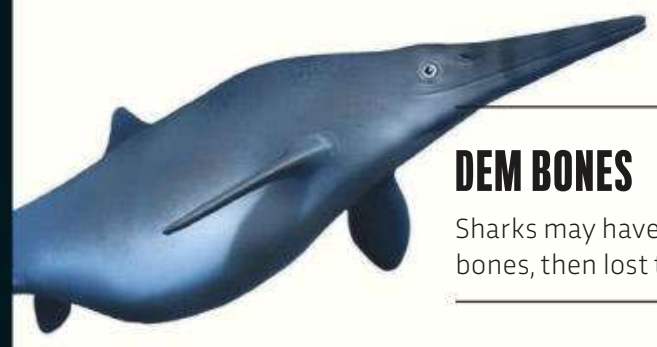

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Sharks may have evolved bones, then lost them **p15**

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DISCOVERIES

POSSIBLE SIGNS OF ALIEN LIFE DETECTED IN VENUS'S ATMOSPHERE

An international team of astronomers have detected a mysterious molecule which may be the by-product of living cells

A team of astronomers have detected the molecule phosphine in clouds above the surface of Earth's neighbour, Venus. The team suggested that the phosphine could be produced by microbial life floating in the planet's highly acidic clouds.

The researchers spotted the signature of phosphine using the James Clerk Maxwell Telescope (JCMT) in Hawaii, and studied it further with the Atacama Large Millimeter/submillimeter Array (ALMA) in Chile. On Earth, the only sources of phosphine are industrial processes, and microbes that live in an oxygen-free environment. This led the team to consider whether the molecule might be a biosignature of alien life.

"This was an experiment made out of pure curiosity, really – taking advantage of JCMT's powerful technology, and thinking about future instruments," said Prof Jane Greaves of Cardiff University, who led the research team. "I thought we'd just be able to rule out extreme scenarios, like the clouds being stuffed full of organisms. When we got the first hints of phosphine in Venus's spectrum, it was a shock!"

Artist's impression of Venus's surface and atmosphere, with phosphine molecules

ESO

Humongous halo The Andromeda Galaxy has a huge halo of gas p19 **Packs a punch** Mantis shrimp's powerful forelimbs inspire next-gen materials p20 **Stone me!** Engineers recreate a tiny Stonehenge to study its acoustic qualities p22

The researchers made the discovery using the James Clerk Maxwell Telescope (pictured) and the Atacama Large Millimeter/submillimeter Array

So, have the team found signs of alien life? "We have no idea if this is what is going on, but at the moment it seems less impossible than other explanations," said team member Dr Anita Richards of the University of Manchester who coordinated the project with the ALMA telescopes in Chile.

They found the phosphine using a technique called absorption spectroscopy. Absorption spectroscopy analyses the light from a nearby star, in this case the Sun, that has passed through the atmosphere of a planet. Since every molecule will absorb a unique set of wavelengths of light, astronomers can use the star's light to determine what substances are present in the atmosphere.

The amount of phosphine found in the atmosphere is tiny – only 20 molecules in a billion – but it is still far more than the team could explain away.

Dr William Bains, from the Massachusetts Institute of Technology, led the work on finding alternative explanations for the presence of phosphine. They studied sunlight, minerals blown upwards from the surface, volcanoes and lightning, but none of these could produce more than 0.0001 per cent of the phosphine that was found.

"When we got the first hints of phosphine in Venus's spectrum, it was a shock!"

"At the moment, we can't explain how enough phosphine molecules could survive long enough in the Venus cloud decks to allow us to detect it," said Richards.

However, not all scientists are convinced. "I think that the simplest explanation is that we don't understand the photochemistry and geochemistry of the Venusian atmosphere," said Prof Charles Cockell, an astrobiologist at the University of Edinburgh who was not involved in the research. "I would always say that biology is a last resort when you've ruled out all other explanations."

Part of the problem comes down to Venus's inhospitable atmosphere. Even though the clouds provide a comfortable temperature and pressure, any life would have to deal with 90 per cent sulphuric acid. "There's no environment on the Earth similar to that that can sustain life," said Cockell. "So for me, the life explanation is not plausible."

Even so, Cockell is excited. "I think, despite all my negativism, it is very exciting," he said. "There might be planets that are habitable where [phosphine] is a signature of biology. So, being able to detect it in another planetary atmosphere is an immensely important thing to be able to do. It's a really good contribution to the search for life in exoplanets."

The next steps for the team are to spend more telescope time looking at the clouds of Venus, hunting for other biosignatures and studying exactly where the phosphine is found. Future space missions could also play a role in searching our planetary neighbour for signs of life.

News in brief

GOING VEGAN COULD HELP TO FIGHT CLIMATE CHANGE

If land currently used to produce meat and dairy was returned to its native ecosystems, it could remove the same amount of CO_2 as was produced by burning fossil fuels over the last 16 years, a study at New York University has found.

Livestock produce large amounts of methane, a greenhouse gas that is 28 times more powerful than carbon dioxide at trapping heat. The new study says that shifting global eating habits to a fully vegan diet could reduce CO_2 emissions by 547 gigatonnes by 2050. That's equivalent to the last 16 years' worth of fossil fuel CO_2 emissions. Reducing meat consumption by 70 per cent could slash emissions by 332 gigatonnes, equivalent to the last nine years' of fossil fuel CO_2 emissions over the same period.

EVOLUTION

Sharks may have evolved bones and lost them

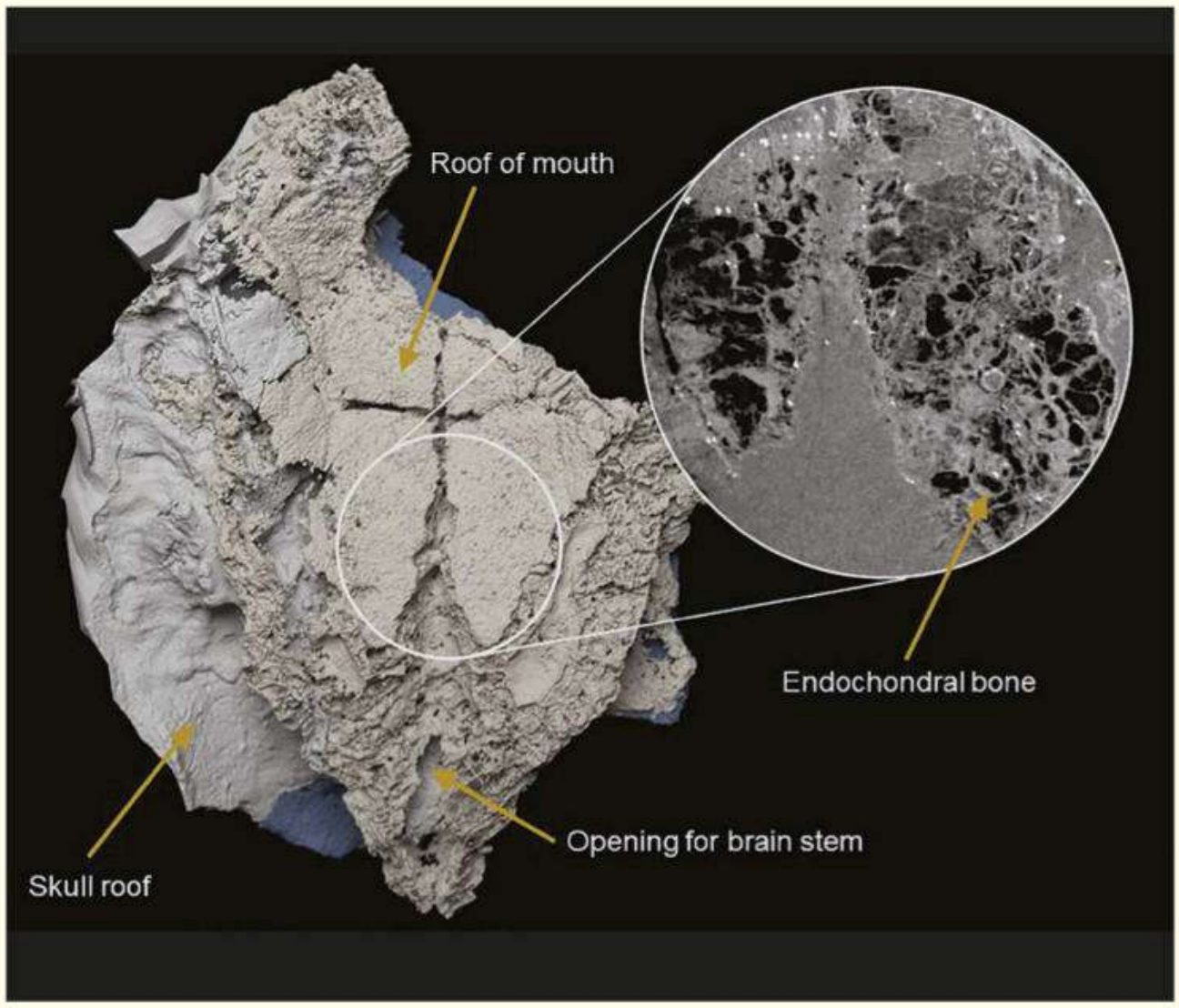
A newly discovered 410-million-year-old fossil of an ancient armoured fish could turn the evolution of sharks on its head.

Today, the majority of vertebrates have skeletons made of bone. But sharks and their relatives, such as rays and skates, have lighter, more flexible skeletons made of cartilage. Conventional wisdom has stated that cartilaginous fish evolved first, with bony fish (like tuna and mackerel) evolving later. Sharks, however, retained their cartilaginous skeleton.

The new fossil, which was discovered by an international team of researchers, has been named *Minjinia turgenensis*. It belongs to a group of armoured fish called the placoderms, and is closely related to the last common ancestor of both sharks and bony fish. When the team uncovered part of its skull, including its braincase, they found that it was made of bone. This suggests that sharks may have first evolved bone and then lost it again, rather than keeping their initial cartilage state throughout their 400 million years of evolution.

"If sharks had bony skeletons and lost it, it could be an evolutionary adaptation," said Dr Martin Brazeau, who took part in the research. "Sharks don't have swim bladders, which evolved later in bony fish, but a lighter skeleton would have helped them be more mobile in the water and swim at different depths. This may be what helped sharks to be one of the first global fish species, spreading out into oceans around the world 400 million years ago."

The majority of early fish fossils have been uncovered in America, Australia and Europe, but new fossils have recently been found in China and South America. *M. turgenensis* was discovered in Mongolia, in rock formations that have never been searched before. The team will now be sifting through the other material they have found, which may help them piece together shark evolution even further.



Virtual three-dimensional model of the braincase of *Minjinia turgenensis* generated from CT scan. Inset shows raw scan data showing the spongy endochondral bone inside

WILL MONTGOMERY/EAO-JCMT, ALAMY, IMPERIAL COLLEGE LONDON/NATURAL HISTORY MUSEUM

DON'T SCRATCH THAT ITCH!

Next time you have an itch, try rubbing it instead of scratching it. Massaging skin activates an anti-itch pathway in the spinal cord that can help to ease irritation, a study in mice published in the *Journal Of Neuroscience* has found.

The research team triggered the urge to scratch in mice by administering an itch-inducing chemical underneath their skin. They then recorded the electrical response from particular neurons in the spinal cord while they stroked the animals' paws. They found that the neurons fired more often as the mice were stroked and less often after the stroking ended. As the neurons respond to both touch and itch, the increase in activity was due to the added touch, not increased itchiness, and the decrease corresponded to itch relief.

MEDICINE

Scientists identify why COVID-19 causes anosmia

The COVID-19 symptom of the loss of the sense of smell, or anosmia, is unusual in the way that it differs from that of the common cold or flu. With colds and flu, a blocked nose is usually the culprit, caused by inflammation of the area. However, for some people that have COVID-19, anosmia is their only symptom.

The reason for this could lie in the mechanism by which the virus infects our cells, new research suggests.

The 'entry point' for SARS-CoV-2, the virus that causes COVID-19, is thought to be a protein found on the surface of some human cells, which are present in the heart, lungs, gut, throat and nose.

The protein, a type of enzyme called the 'angiotensin converting enzyme II' (ACE-2), has a particular shape that enables it to take the hormone angiotensin, and convert it into angiotensin II, which is used around the body for things like regulating blood pressure. While ACE-2's shape fits nicely with angiotensin, it also binds with the spiky outer proteins of the coronavirus.

By looking at tissue samples from people's noses, a team of scientists from Johns Hopkins University School of Medicine hoped to quantify how many ACE-2 proteins were found on each type of cell. They discovered that the levels of the protein on the olfactory epithelium, the tissue at the back of the nose which is used to detect smell, were 'strikingly' high, between 200 and 700 times higher than in other areas of the nose.

"These olfactory-supporting cells are necessary to protect and maintain the delicate neurons in the nose that detect odours and signal that information to the brain," said author of the study Prof Andrew P Lane. "Generally speaking, when cells are infected with a virus, they undergo a process called pyroptosis – essentially hitting the self-destruct button to foil the virus. So, most likely, olfactory-supporting cells destroy themselves, leading in turn to the death of sensory neurons and loss of the sense of smell."

Further studies looking at recovery of COVID-19 patients have found these neurons do return over time, though the long-lasting effects are still unknown.

"Some COVID-19 patients are reporting distorted smell – parosmia – persisting for months after their sense of smell has returned… this long-lasting smell disturbance with COVID-19 is unusual and warrants further study. It is possible that this altered smell function may be permanent, but it is too soon to know. We are optimistic that this eventually goes away as the brain 're-learns' to interpret signals from the regenerated olfactory lining," Lane said.

It's thought that this finding could indicate potential avenues for treating the infection directly through the nose.

In numbers

28 trillion

The amount of ice, in tonnes, the Earth lost between 1994 and 2017, according to UK-based scientists.

BIOLOGY

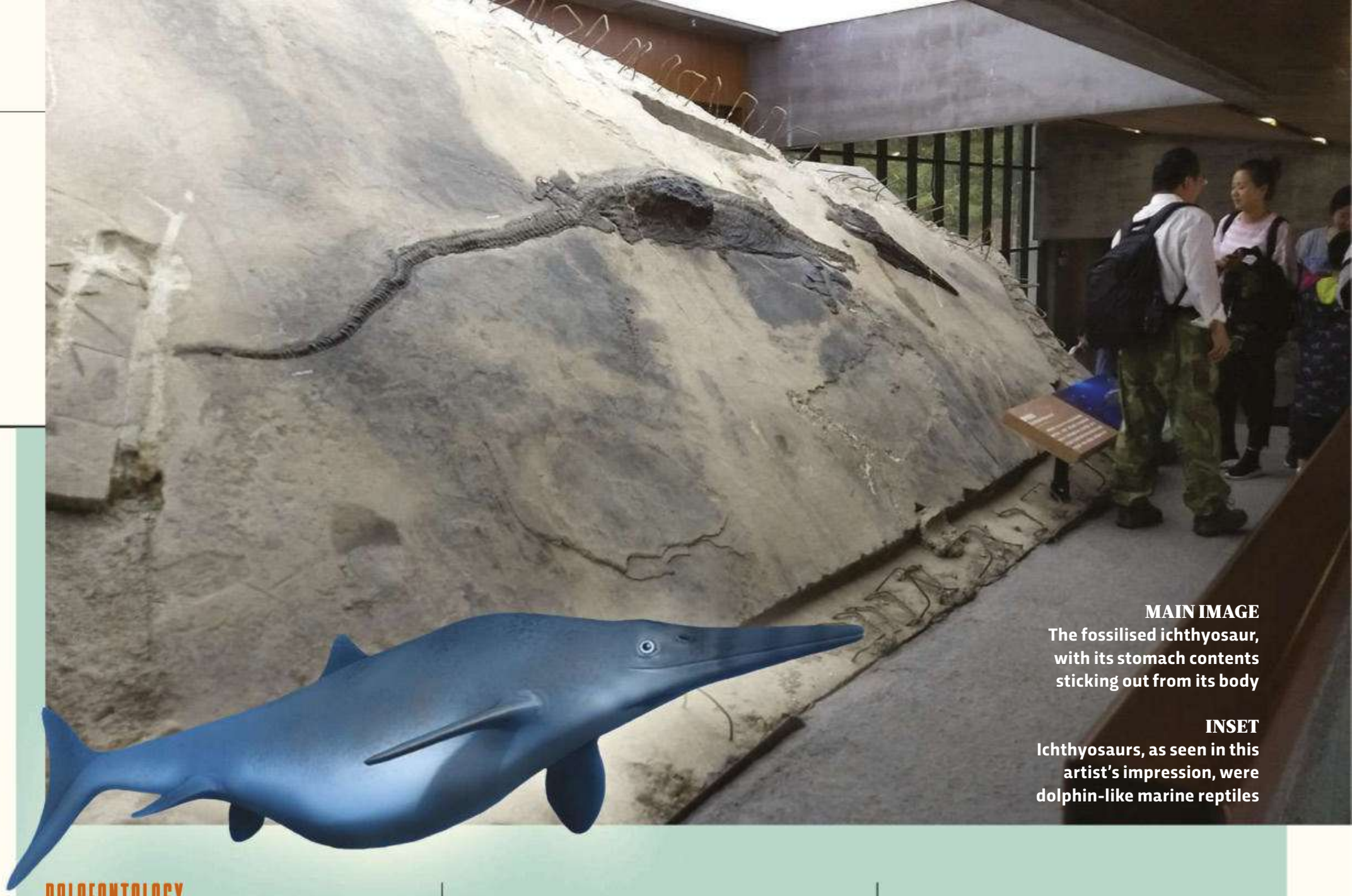
178 terabits per second

The record-breaking data transmission rate recently achieved by researchers at University College London – that's fast enough to download the entire Netflix library in less than a second.

8°C

The average global temperature of the last ice age, as calculated by a team from the University of Arizona. Known as the Last Glacial Maximum, it took place around 20,000 years ago. Currently, the average global temperature figure sits at 14°C.

GETTY IMAGES X2, RYOSUKE MOTANI, JIANG ET AL



MAIN IMAGE
The fossilised ichthyosaur, with its stomach contents sticking out from its body

INSET
Ichthyosaurs, as seen in this artist's impression, were dolphin-like marine reptiles

PALAEONTOLOGY

Supersize me: fossil reveals ancient marine reptile's enormous final meal

"Our ichthyosaur's stomach contents weren't etched by stomach acid, so it must have died quite soon after ingesting this food item"

A 240-million-year-old fossil has revealed that dolphin-like ichthyosaurs could gobble up animals almost as big as themselves. It's the first direct evidence of 'megapredation' – one large animal eating another – in the ancient world.

Ichthyosaurs were marine reptiles that lived during the time of the dinosaurs. The fossilised ichthyosaur in this new study was uncovered in a quarry in southwestern China. It's an almost complete skeleton, around five metres long, with the bones of another marine reptile called a thalattosaur preserved inside its stomach.

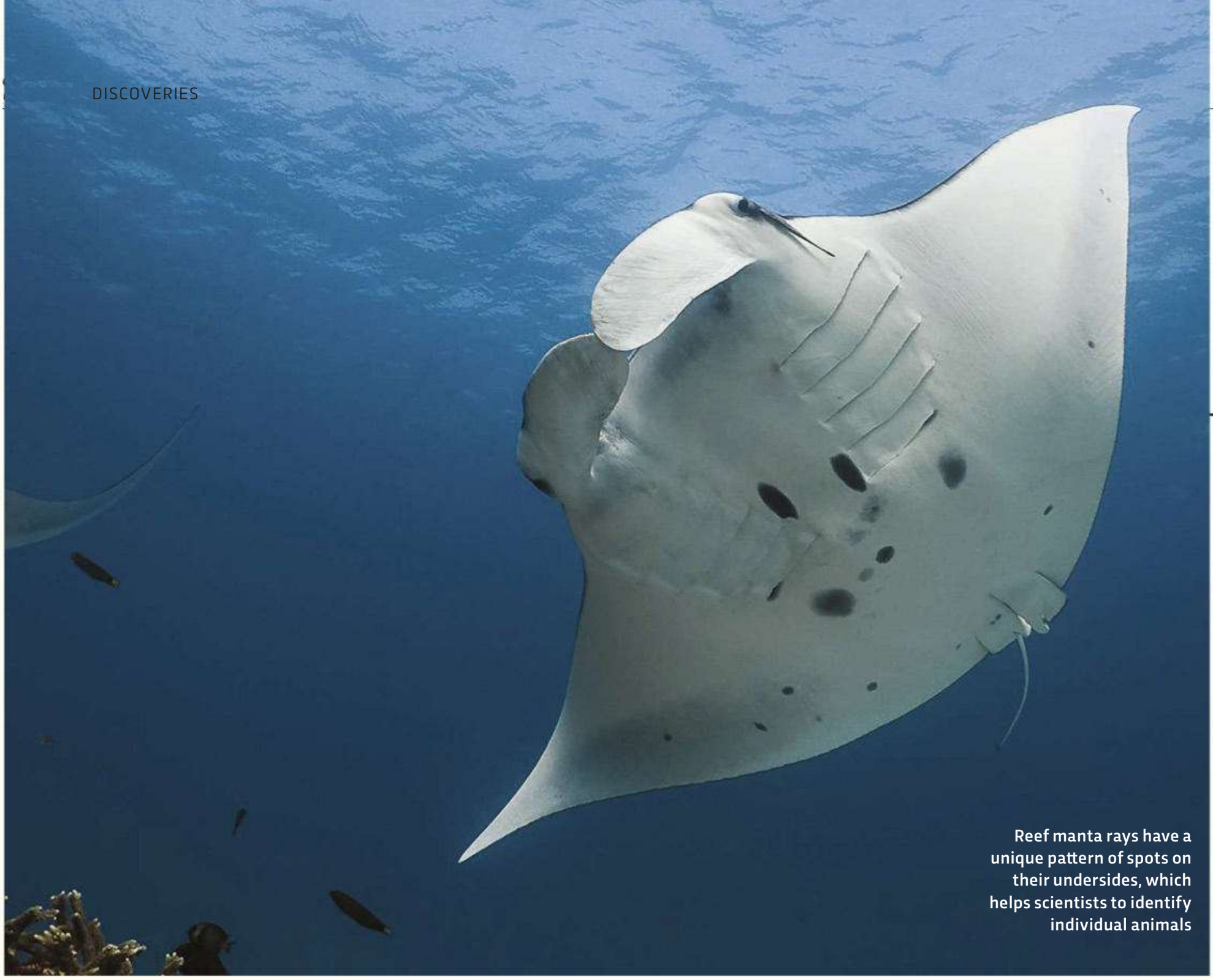
The thalattosaur was around four metres long and more lizard-like than the ichthyosaur, with four paddling limbs. The bones found inside the ichthyosaur's stomach correspond to the thalattosaur's middle section, from its front to back limbs.

"Our ichthyosaur's stomach contents weren't etched by stomach acid, so it must have died quite soon after ingesting this food item," said study co-author Dr Ryosuke Motani, a palaeobiologist at the University of California, Davis.

The researchers don't know for sure whether the ichthyosaur killed the animal itself, or whether it was scavenging another predator's kill. But several pieces of evidence suggest that it was a direct kill, including the fact that the nutritious torso and legs were still intact – this probably wouldn't have been the case if another predator had got there first.

The ichthyosaur had relatively small, peg-like teeth, suggesting that, rather than neatly slicing through its victim, it would have gripped it before ripping or tearing it apart. Predators such as orcas, leopard seals and crocodiles use a similar technique.

"Now, we can say for sure that [ichthyosaurs] did eat large animals," said Motani. "This also suggests that megapredation was probably more common than we previously thought."



Reef manta rays have a unique pattern of spots on their undersides, which helps scientists to identify individual animals

MARINE BIOLOGY

Reef manta rays make long-term use of protected areas

Reef manta rays like hanging out in marine protected areas, according to new research carried out by scientists in Australia

Reef mantas (*Mobula alfredi*) are one of the world's biggest ray species, inhabiting tropical and subtropical regions of the Indian and West Pacific Oceans. Their habit of frequenting shallow waters around coastal reefs makes them an iconic animal for ecotourism, but also makes them a target for the fisheries that hunt them for their body parts, which are highly prized in traditional medicine. The ocean giants are listed as 'vulnerable' on the IUCN Red List of Threatened Species.

Their migration movements are little understood, so a team of researchers from Australia wanted to change that in order to help with conservation efforts. They used satellite tags and more than a decade's worth of photographic data to identify 1,121 individual animals that live and travel between Ningaloo Coast and Shark Bay – two UNESCO World Heritage Areas on Australia's western coast.

"Satellite tags allow us a short peek into the secret lives of these animals to understand where else they frequent outside of key tourism locations, while photographic identification helps us track visitation over longer periods," explained lead author Amelia Armstrong, from the University of Queensland.

Although reef mantas are capable of migrations of at least 1,100km, the team found that many of the individuals they studied had a long-term affinity to locations in Ningaloo, with 9.8 per cent of the individuals remaining there for more than 10 years. The greatest distance a ray travelled after tagging was 700km.

"This is a great discovery for the reef manta rays on this coastline, because these protected areas provide the legislative framework needed to underpin further management action," said Armstrong.

BITUMEN ADDS TO AIR POLLUTION IN TOWNS

Bitumen found in roads, roof and driveways is a significant source of air pollution in urban areas, particularly on sunny days, a study by researchers at Yale University has found. They found that when heated, fresh bitumen released a complex mixture of compounds, including many hazardous pollutants. They say that these can lead to secondary organic aerosol (SOA), a major contributor of $PM_{2.5}$ – a type of particulate air pollution comprising particles smaller than 2.5 micrometres in diameter, which has substantial public health effects. The researchers also examined what happens when bitumen is exposed to solar radiation and saw a significant jump in emissions – up to 300 per cent for road bitumen – demonstrating that solar radiation, and not only temperature, can lead to an increase in emissions.

SPACE

Andromeda Galaxy has a humongous halo of gas

Astronomers using the Hubble Space Telescope have mapped the enormous halo of gas surrounding the Andromeda Galaxy – the closest large galaxy to our Milky Way.

The map, which is the most detailed of its kind, shows that the halo of plasma (electrically charged gas) surrounding this spiral galaxy extends about 1.3 million light-years towards the Milky Way (about half of the distance), and as much as two million light-years in some directions.

The halo is invisible, but the researchers say that if it could be seen, it'd be about three times the width of the Plough, making it the biggest feature in the night sky.

"Understanding the huge halos of gas surrounding galaxies is immensely important," said team member Samantha Berek at Yale University. "This reservoir of gas contains fuel for future star formation within the galaxy, as well as outflows from events such as supernovae. It's full of clues regarding the past and future evolution of the galaxy, and we're finally able to study it in great detail in our closest galactic neighbour."

The team found that Andromeda's halo is composed of two distinct layers. The inner 'shell' has a more complex structure than the outer shell, which is likely the result of supernovae in the galaxy's disc. These violent explosions – the death throes of giant stars – also eject heavy elements into space, which were detected in high amounts in the halo.

The halo was mapped by studying the ultraviolet light from 43 distant quasars – extremely luminous galactic cores that are powered by black holes – located behind the halo. The researchers used Hubble's Cosmic Origins Spectrograph instrument to analyse how this background light was absorbed by the halo's gas in different regions, revealing variations in the gas's structure.

Andromeda is thought to be similar in size and shape to our Milky Way, so these findings also provide insights into our own galactic halo, which is much trickier to map from our position inside the Milky Way.

The gaseous halo surrounding the Andromeda Galaxy, if it could be seen with the naked eye

SHUTTERSTOCK, NASA, AMELIA J ARMSTRONG

They did what?

Researchers paint eyes onto cows' bums

WHAT DID THEY DO?
Dr Neil Jordan, a biologist from the University of New South Wales, Australia, painted eyes on the rear ends of cattle in the Okavango Delta region of Botswana.

WHY DID THEY DO THAT?
After hearing reports of a group of local farmers killing a pair of lionesses in retaliation for them preying on their herds of cattle, Jordan wanted to figure out a non-lethal solution to the problem. He took his inspiration from butterfly wings that sport eye-like patterns to ward off preying birds, and accounts of Indian woodcutters who wear masks on the back of their heads to deter tigers.

WHAT DID THEY FIND?
Following a four-year trial involving hundreds of animals, Jordan and his team found that cattle with eyes painted on their rumps were significantly more likely to survive than those that had crosses painted on their bums and those that weren't painted at all.

MARINE BIOLOGY

The mantis shrimp is armed with two calcified clubs and can deliver the world's fastest punch

Mantis shrimp 'clubs' could inspire next-gen super tough materials

They may be little more than 10cm long, but mantis shrimp pack a serious punch. They are able to whip out their club-like forelimbs at a whopping 23 metres per second, smashing them into their prey with the force of rifle bullet. Yet despite this tremendous impact, these ancient crustaceans can throw blow after blow, without sustaining damage.

Now, material scientists at the University of California, Irvine, have discovered that these clubs have a uniquely designed nanoparticle coating that absorbs and dissipates energy. This finding could have significant implications for engineered materials in the automotive, aerospace and sports industries, they say.

"Think about punching a wall a couple of thousand times at those speeds and not breaking your fist," said lead researcher Prof David Kisailus. "That's pretty impressive, and it got us thinking about how this could be."

The team used transmission electron microscopes (TEM) and atomic force microscopes (AFM) to examine the nanoscale architecture and materials that make up the surface layer on the clubs. They found that the nanoparticles are made of intertwined organic proteins and polysaccharides, and inorganic calcium phosphate nanocrystals. The inorganic nanocrystals are stacked together like Lego pieces, but with small differences in orientation where they join together.

"The high-resolution TEM really helped us understand these particles, how they're architected and how they react under different types of stress. At relatively low strain rates, the particles deform almost like a marshmallow and recover when the stress is relieved," Kisailus said.

But at high strain rates, they behave differently. "The particles stiffen and fracture at the nanocrystalline interfaces. When you break something, you're opening up new surfaces that dissipate significant amounts of energy."

The structure could be imitated and used to engineer similar particles to add enhanced protective surfaces for use in cars, aircraft, cycle helmets and body armour, the researchers say.

GETTY IMAGES, DARPA, KUNDRAT ET AL/CURRENT BIOLOGY ILLUSTRATIONS: CATHAL DUANE

AI PILOT DEFEATS HUMAN PILOT IN SIMULATED DOGFIGHTS

Watch out, Maverick, there's a new top gun in town. Heron Systems' F-16 AI pilot has taken first place in DARPA's AlphaDogfight Trials, beating an experienced human Air Force F-16 pilot 5-0 in a series of simulated air battles. The trials took place over three days in August and were streamed live on ZoomGov and YouTube as part DARPA's Air Combat Evolution (ACE) programme, which seeks to automate air-to-air combat. "This was a crucible that lets us now begin teaming humans with machines, which is at the heart of the ACE programme where we hope to demonstrate a collaborative relationship with an AI agent handling tactical tasks like dogfighting, while the onboard pilot focuses on higher-level strategy," said Colonel Dan 'Animal' Javorsek, programme manager in DARPA's Strategic Technology Office.

3D scans of an unhatched sauropod embryo have revealed they may have had binocular vision and a prominent facial horn

PALAEONTOLOGY

Fossilised dino skull reveals adorable appearance of baby sauropods

The first 3D scan of a sauropod embryo's skull has revealed what these gigantic dinosaurs looked like as tiny hatchlings.

Sauropods are a group of dinosaurs that are instantly recognisable by their small heads and their long, sweeping necks and tails – *Diplodocus* and *Brontosaurus* are two of the best-known examples.

The first sauropod embryos were discovered around 25 years ago in an 80-million-year-old nesting ground of titanosaurs (a group of especially large sauropods) at a site called Auca Mahuevo in the Patagonian region of Argentina.

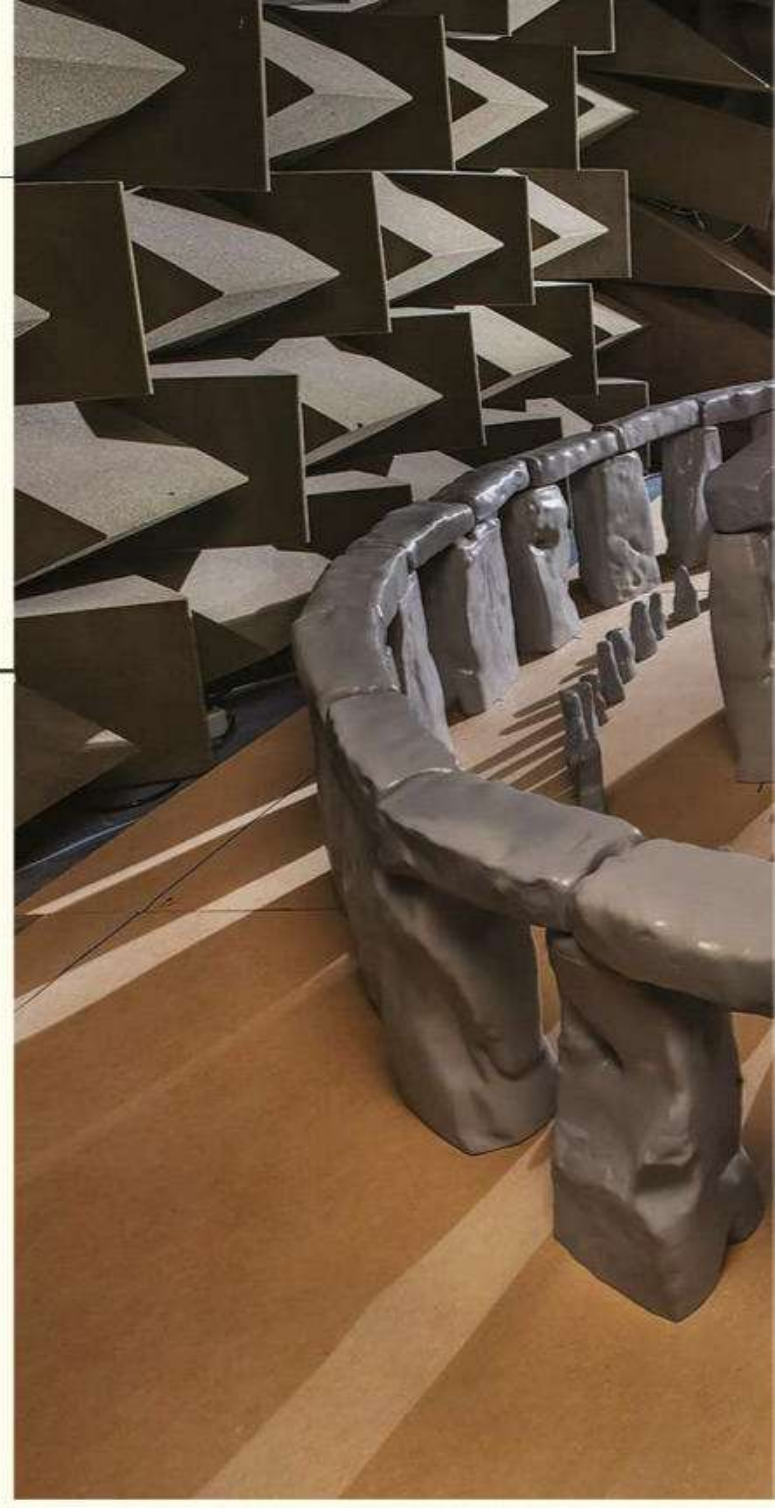
The newly analysed skull also belongs to a titanosaur from Patagonia, although the researchers don't know the exact location, as the fossilised egg it was found in was originally smuggled out of the country, and only came to the researchers' attention later on.

The team used an X-ray imaging technology called synchrotron microtomography to analyse the inner structure of the skull's bones, teeth and soft tissue. This uncovered hidden details, including tiny teeth preserved deeply in the jaw sockets, and even what appear to be the remains of chewing muscles.

The position of the embryo's eye sockets also suggests that, unlike adults, the freshly hatched sauropods may have had a form of binocular vision, in which the slightly different images from each eye give an improved perception of depth – perhaps helping it to better detect predators. The embryo also has an unusual horn-like structure at the tip of its face, which isn't present in adults.

"Our study revealed several new aspects about the embryonic life of the largest herbivorous dinosaurs that lived on our planet," said study leader Dr Martin Kundrát, a palaeobiologist at Pavol Jozef Šafárik University in Slovakia. "A horned faced and binocular vision are features quite different from what we expected in titanosaurian dinosaurs."

PROF TREVOR COX
Acoustics engineer



SALFORD ACOUSTICS

Horizons

Stonehenge acted like an ancient acoustic chamber

Engineers have 3D printed a scale model of Stonehenge in order to investigate the effect its structure would have had on conversations, rituals and music

STONEHENGE IS NOW IN AN INCOMPLETE STATE. HOW DID YOU ACCURATELY RECONSTRUCT WHAT IT WOULD HAVE LOOKED LIKE THOUSANDS OF YEARS AGO?

Well, the first thing is as an acoustics professor is not to do it myself, but to talk to the archaeologists because I'm not the expert. We think of Stonehenge as being one fixed thing but it went through many stages. At first it was a large stone circle, maybe 100 metres across, back in 2900 BC. The model we're looking at is from 2500 BC, so it's still pretty old. At this point there were 157 stones. Now, quite a lot are either lying on the floor or actually completely missing.

Historic England did a reconstruction of the monument at different states when it was putting together its new visitor centre a few years back. And we used that data, which is based on some of the latest archaeological evidence, to establish how the stone circles may have been in the past.

WHY DID YOU CHOOSE TO RECREATE STONEHENGE ON A 1 TO 12 SCALE?

Well, a few people have suggested it was because I was aping the famous scene in *This Is Spinal Tap* where they have a model of Stonehenge made, which is disappointingly small. It is 1 to 12 scale because they mixed up inches and feet. But that was pure coincidence. We had to fit it [our model] in a semi-anechoic chamber – a room which has got very absorbent walls. And it was literally 'what's the biggest model we could fit in this room?' As models get smaller and smaller you get problems with things like air absorption, it gets harder to get loud speakers that work properly. So you try to work in the biggest scale you can get away with. The model of Stonehenge is about two and a half metres across, which just about fitted in our chamber.

WHAT SORT OF SOUNDS WERE YOU USING?

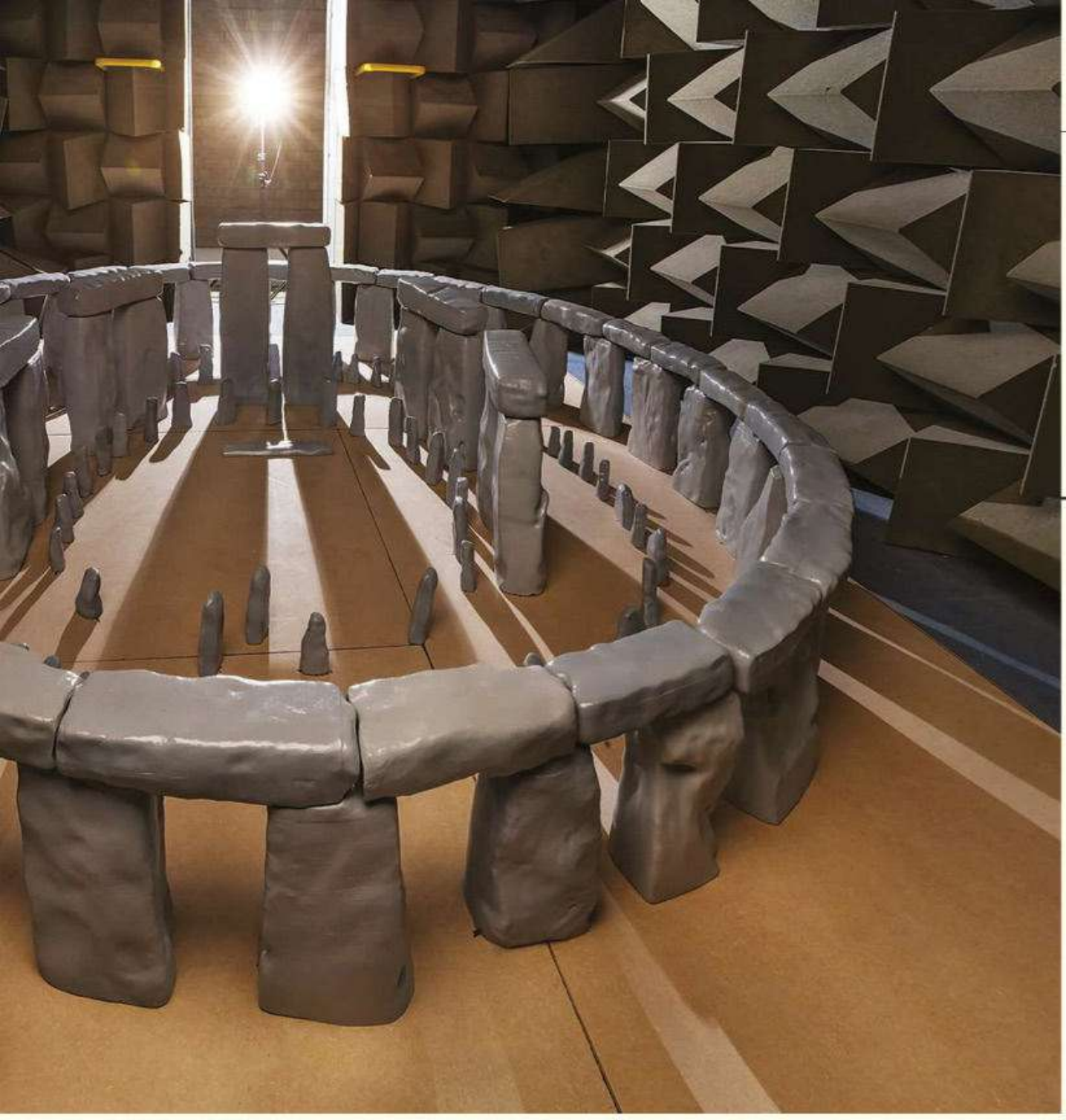
When we tested it, we played what's called a sine sweep. So it's a sweeping frequency. You could hear it when it starts off [at low frequency] and then it would disappear but still be going. We used the sine sweep because we wanted to measure every single frequency.

Then there's a mathematical process called deconvolution; this gets to what we really want, which is called the impulse response. The equivalent is if you go into a room and you clap your hands and pick the sound up on a microphone, you get the response of the room to the impulse. The impulse being a handclap in that case.

ONCE YOU COLLECTED YOUR RAW DATA, HOW DID YOU GO ABOUT PROCESSING IT?

Once you've got the impulse response, which is the acoustic sonic fingerprint of a space, there's various ways we process it to look at how people might respond [to the sound]. So when we design, say, a concert hall, there's a set of parameters that we derive from

"We don't know exactly what music they may or may not have been making, but we know music sounds better with some reverberation"



The 3D printed scale model of Stonehenge in a semi-anechoic chamber

this impulse response through some calculations that we know correlate really well with people's hearing. One of those is reverberation time. If you go into a cathedral and speak, the sound rattles around for a long time before dying away to nothing. The time this takes is called the reverberation time. It's the oldest parameter in architectural acoustic design. So that's the first thing we calculated. For the Stonehenge model, we got a reverberation time in the mid frequencies of about 0.6 to 0.7 seconds. That's maybe like a cinema. Cinemas have got a little bit of reverberation. So, you'd hear your voice being supported by reflections, and musical notes would be slightly enhanced, but the effect would be quite subtle.

WHAT KEY THINGS DID YOU FIND?

It depends on where you're looking, but sound was amplified, due to reflections, by about four decibels in the model on average. You can imagine a case where you're trying to talk and your speech is only just audible. You're talking across a large distance in this place, potentially 30 metres. Maybe there's a bit of noise from the crowd, but that four decibels can be just enough to lift your voice to make more of your speech audible. It's particularly true if the crowd was big enough that you couldn't face all of them at once. Then actually these reflections are really useful in evening out the fact that the voice is more powerful in some directions than in others. So the amplification is the first thing. And that would make music sound better as well. Anything louder tends to sound a bit better. But then you also get this reverberation. We don't know exactly what music they may or may not have been making, but we know in general that music sounds better with some reverberation. So, we can imagine it [Stonehenge's design] would improve the quality of music.

HOW WOULD IT HAVE AFFECTED SPEECH?

If you listen back to our recordings, you can do what's called 'auralisation' and add some speech to it and hear what it sounds like. You can hear the effects of the stones, but you can hear there's much more bass in people's voices. It's a bit like going into your bathroom and singing. That's because the way that sound interacts with the stones varies with frequency. For example, the ground is a bit more absorbing at high frequency. So that sound tends to die away quicker. But you've also got the fact that the size of the sound's wavelength determines how it reacts with the different stones and the gaps between them. So if you have a sound wave that is roughly the same size as the stone, you get a scattering effect. If the sound wave is much smaller than the stone, which is what happens at high frequencies, you get a direct reflection. At low frequencies, sound struggles to escape between the gaps of these very large uprights because the gap's a bit too small and so the sound gets constrained so you get a bass boost. At high frequency it's easier for it to disappear down the gap because the sound wave is smaller than the gap.

DO YOU THINK THAT THESE ACOUSTIC PROPERTIES OF STONEHENGE ARE THERE BY DESIGN?

I think that's fairly unlikely because we know that the reconfigurations of Stonehenge didn't change the acoustics in a particularly audible manner. I think it's much more likely they were designing it for other reasons, but it then had acoustics that they could exploit. I think they would be a bit daft not to exploit the sound that's there.

PROF TREVOR COX

Trevor is a professor of acoustic engineering at the University of Salford, author and radio broadcaster. ***Interviewed by*** **BBC Science Focus** ***commissioning editor Jason Goodyer***

WILDLIFE

Wildlife Photographer of the Year teases this year's entries

The annual exhibition will open to the public in London's National History Museum on 16 October 2020

1. The spider's supper
by Jaime Culebras, Spain
A wandering spider chows down on the eggs of a giant glass frog in a stream in Manduriacu Reserve, northwestern Ecuador.

2. Head start
by Dhritiman Mukherjee, India
Male gharials, like this one photographed in the National Chambal Sanctuary in Uttar Pradesh, northern India, mate with several females who all nest close together to produce a huge brood of hatchlings.

3. Paired-up puffins
by Evie Easterbook, UK
Every spring, the Farne Islands off the coast of Northumberland attract more than 100,000 breeding pairs of seabirds. Here, a pair of Atlantic puffins sit nestled in their burrow.

4. Treetop douc
by Arshdeep Singh, India
This red-shanked douc langur was snapped near Son Tra Nature Reserve, Vietnam's last coastal rainforest. Found only in Vietnam, Laos and Cambodia, the primate is threatened by habitat loss, hunting and trade.

5. A risky business
by Quentin Martinez, France
A market trader slices up fruit bats in Tomohon Market in northern Sulawesi, Indonesia. COVID-19 is thought to have originated in a similar market in China, leading to calls to ban the sale and butchery of live wild animals.

NATURAL HISTORY MUSEUM/WILDLIFE PHOTOGRAPHER OF THE YEAR 2020

2

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5

WILDLIFE

Hundreds of species, including critically endangered apes, potentially at risk from COVID-19

More than 400 different species of vertebrates, including birds, fish, amphibians, reptiles and mammals, could potentially contract the virus that causes COVID-19, researchers at the University of California, Davis have found.

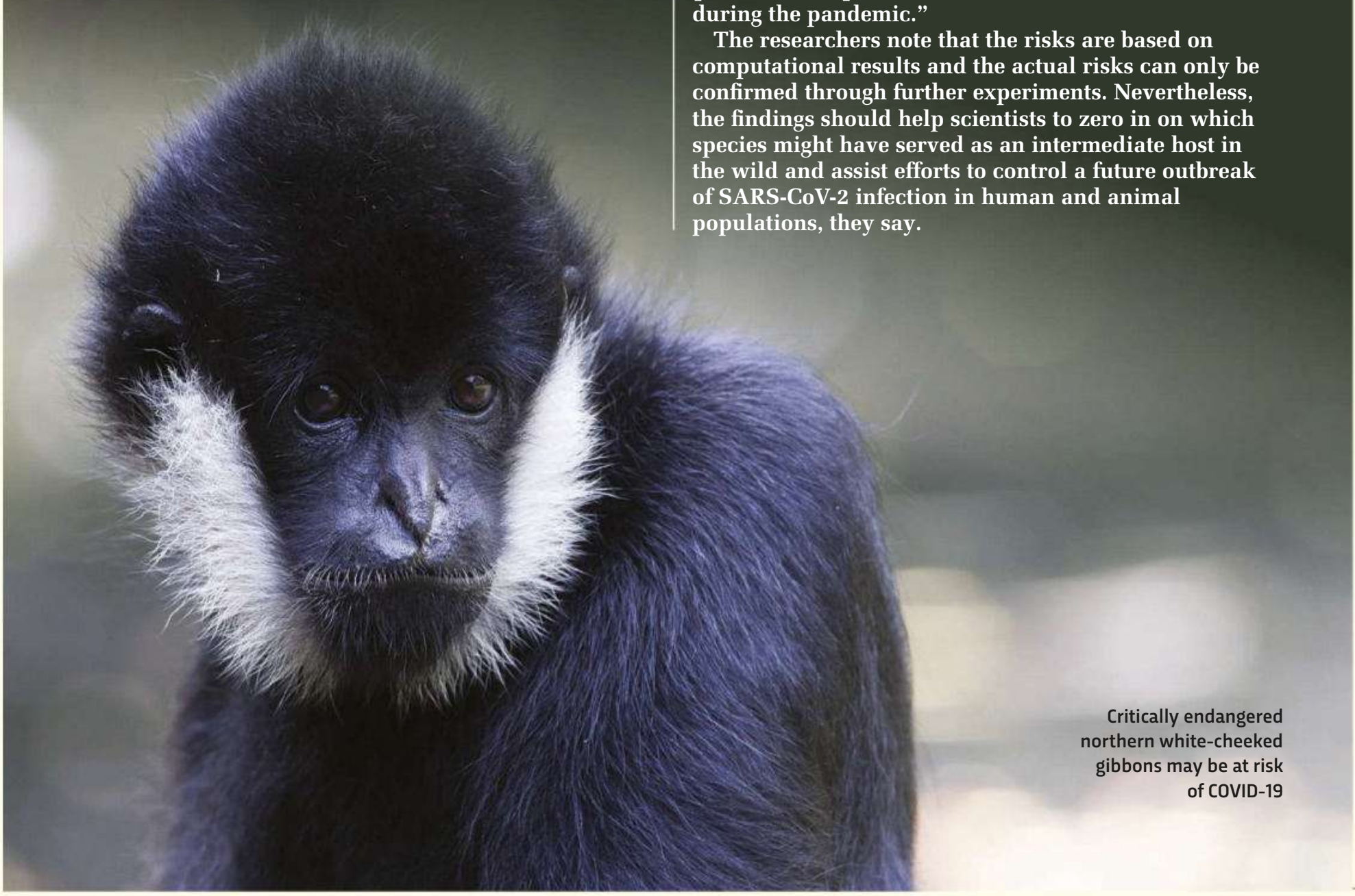
The team used genomic analysis to compare the main cellular receptor for the virus in humans – angiotensin-converting enzyme-2, or ACE2 – in 410 different species of vertebrates. ACE2 is found on many different types of cells and tissues, including cells lining the nose, mouth and lungs. In humans, 25 amino acids that make up ACE2 are involved in the mechanism by which the virus binds to and gains entry into cells. The researchers therefore wanted to investigate any similarities in animals.

"Animals with all 25 amino acid residues matching the human protein are predicted to be at the highest risk for contracting SARS-CoV-2 via ACE2," said postdoctoral research assistant Dr Joana Damas. "The risk is predicted to decrease the more the species' ACE2 binding residues differ from humans."

About 40 per cent of the species potentially susceptible to SARS-CoV-2 are classified as 'threatened' by the International Union for Conservation of Nature and may be especially vulnerable to human-to-animal transmission. This includes several critically endangered primate species, such as the Western lowland gorilla, Sumatran orangutan and northern white-cheeked gibbon, that are predicted to be at a very high risk of infection by SARS-CoV-2 via their ACE2 receptors. Other animals flagged as high risk include marine mammals such as grey whales and bottlenose dolphins, as well as Chinese hamsters. Domestic animals such as cats, cattle and sheep were found to have a medium risk, and dogs, horses and pigs were found to have low risk for ACE2 binding.

"The data provide an important starting point for identifying vulnerable and threatened animal populations at risk of SARS-CoV-2 infection," said lead author Prof Harris Lewin. "We hope it inspires practices that protect both animal and human health during the pandemic."

The researchers note that the risks are based on computational results and the actual risks can only be confirmed through further experiments. Nevertheless, the findings should help scientists to zero in on which species might have served as an intermediate host in the wild and assist efforts to control a future outbreak of SARS-CoV-2 infection in human and animal populations, they say.



Critically endangered northern white-cheeked gibbons may be at risk of COVID-19

GETTY IMAGES X2 ILLUSTRATIONS: CATHAL DUANE

CORONAVIRUS

COVID-19 highly likely to become seasonal disease

It looks like cold and flu season could become 'cold, flu and COVID-19' season

According to a paper by scientists in Lebanon and Qatar, transmission of the coronavirus SARS-CoV-2 has been more aggressive in temperate regions during winter months. If this pattern persists, it could mean that transmission peaks in winter, becoming a seasonal virus like flu, and other respiratory viruses that cause the common cold.

The seasonality of viruses is affected by a number of factors. Flu tends to peak in winter because people spend more time indoors in close proximity to each other; our immune systems are often weaker in the winter; and the flu virus is more stable at lower temperatures.

The latest knowledge on the stability and transmission of SARS-CoV-2 suggests that COVID-19 might follow a similar pattern. "We think it's highly likely, given what we know so far, that COVID-19 will eventually become seasonal," said Dr Hassan Zaraket at the American University of Beirut in Lebanon.

But the researchers stress that this will only happen once herd immunity is reached, which is where enough people have achieved some level of immunity to COVID-19 – either through contracting the disease or through vaccination – for the disease's spread to be halted.

It's not yet known what percentage of the population will need to become immune for this to happen. But once we reach that point, transmission of COVID-19 should drop off during the summer months as seasonal factors start to have more influence.

Until then, the coronavirus "will continue to cause outbreaks year-round," said Zaraket. "Therefore, the public will need to learn to live with it and continue practising the best prevention measures, including wearing of masks, physical distancing, hand hygiene and avoidance of gatherings."

RURAL KIDS
Researchers at Hasselt University in Belgium have found that children aged between 7 and 15 had a higher IQ by 2.6 points, and scored lower for difficult behaviour, if they lived in areas with increased greenery.

CONSERVATIONISTS
Up to 48 bird and mammal extinctions have been prevented by global conservation efforts since 1993, a study from Newcastle University and BirdLife International has found.

Good month

Bad month

LAB-GROWN MEAT
Nearly three-quarters of Generation Z, those born between 1995 and 2015, are unwilling to eat lab-grown meat, despite being concerned about the environment, a study carried out at the University of Sydney has found. Time to buy shares in lentil burgers.

NAP TAKERS
Taking a daily nap of more than 60 minutes could increase your risk of heart disease and early death, a study of 13,651 people carried out at Guangzhou Medical University in China has found. The effect could be due to people taking naps to make up for a proper night's sleep, they say.

PC Specialist recommends Windows

Windows 10

COSMOS ELITE

15.6" Matte Full HD 120Hz Screen
Intel® Core™ i5-10300H
8GB Corsair 2133MHz
4GB GeForce GTX 1650
1TB SEAGATE 7mm SATA HDD (5,400)
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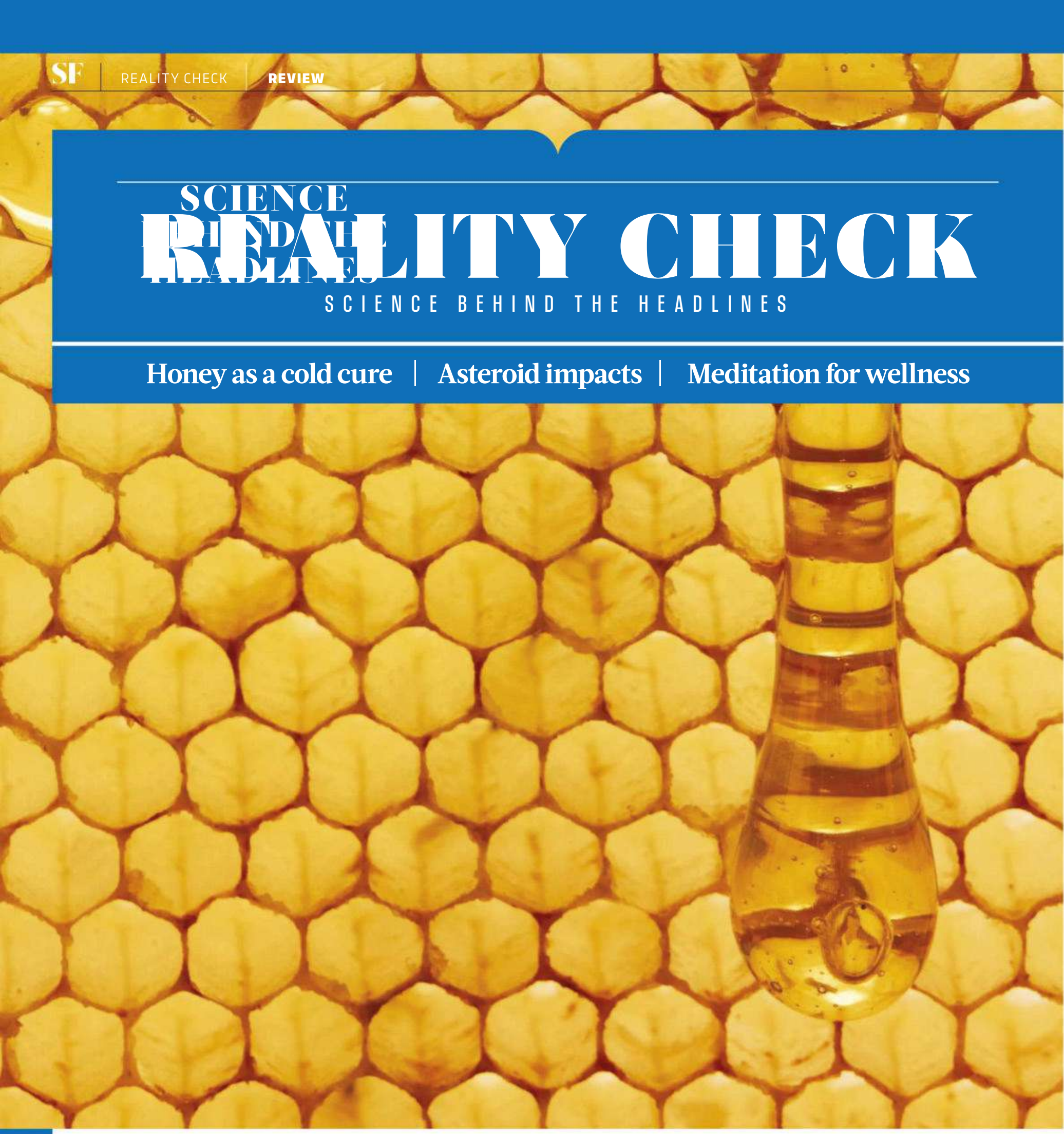
SCIENCE BEHIND THE HEADLINES

REALITY CHECK

SCIENCE BEHIND THE HEADLINES

Honey as a cold cure | Asteroid impacts | Meditation for wellness



REVIEW

HONEY: COULD IT HELP CURE A COLD?

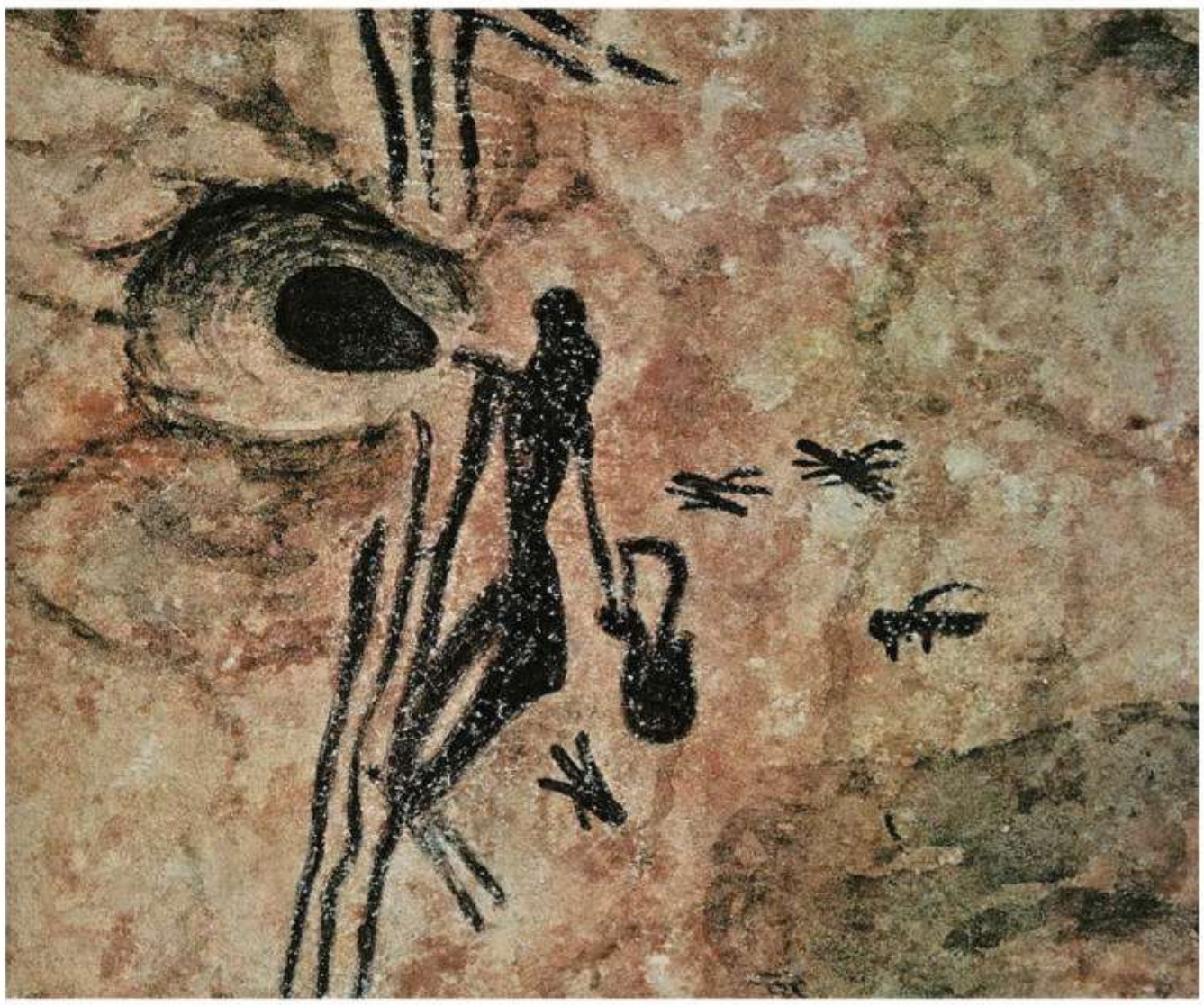
A recent review suggested that honey could be 'superior' to other forms of care for the common cold, but some experts have questioned the research. So, is honey nature's remedy for a cold, or just an old wives' tale?

"Antibiotics can have side effects like diarrhoea and vomiting, rashes and allergic reactions. Worse still, it causes antibiotic resistance"

BBC *Visit the BBC's* Reality Check *website at* ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

Honey has been used by humans for thousands of years. Descriptions of its medicinal use can be found in the Qur'an and the Bible, as well as in texts by Hippocrates, the Greek physician credited with devising the Hippocratic Oath and considered one of the fathers of early medicine. An 8,000-year-old cave painting, discovered in Spain in 1924, depicts a man gathering honey from a hive.

It's now known that honey is antimicrobial. Studies have shown its effectiveness in fighting *Salmonella* and *E. coli* bacteria, and a medical-grade honey is used to treat some wounds, thanks to its anti-inflammatory properties.



GETTY IMAGES, ALAMY

BELOW An 8,000-year-old cave painting, depicting a person gathering honey

CAN HONEY TREAT THE COMMON COLD?

Honey is a home remedy usually offered to cold and flu sufferers, but the evidence for its effectiveness has only recently been systematically reviewed.

Scientists at the University of Oxford found that honey was 'superior' in soothing symptoms for those with a cold, flu or other upper respiratory tract infection (URTI). They reviewed 14 different studies, each comparing honey to another method of care, such as cough suppressants, steroids and antibiotics.

However, epidemiologist Gideon Meyerowitz-Katz questioned the quality of the studies included, and therefore the validity of the conclusion that honey could be better than usual care methods.

"Certainly the studies included were not the finest trials ever conducted," says Dr Joseph Lee, one of the authors of the new study. "Ultimately that's why we have called for more studies to be done. In clinical medicine, we have to decide what to do now, based on what is available."

DOES THIS NULLIFY THE FINDINGS?

"It makes us less confident that honey is effective, but it doesn't change the recommendation, given that the alternatives don't work, or are harmful," says Lee. "For example, we know that people end up taking antibiotics for URTIs. In fact, this is one of the biggest reasons for antibiotic consumption. Antibiotics can have side effects like diarrhoea and vomiting, rashes and allergic reactions. Worse still, it causes antibiotic resistance that threatens the future of medicine."

Honey consumption, on the other hand, has a good safety profile, says Lee. But honey is also an extremely variable product. It can contain 200 different substances, including proteins, vitamins and minerals. Primarily, though, honey is sugar and water.

“It is the sweetness that is the common factor across honey, cough medicines and sore throat lozenges”

SO SHOULD I EAT HONEY, IF I HAVE A COLD?

It is well recognised that syrups, including honey, have a demulcent effect: relieving irritation by forming a film on the throat. Over-the-counter cough medicines emulate this with added sugar, the sweet taste stimulating salivation and mucus secretions that soothe and lubricate the airway.

“It is the sweetness that is the common factor across honey, cough medicines and sore throat lozenges,” says Prof Ron Eccles, who ran the Common Cold Centre at Cardiff University for nearly 30 years. All three will be just as effective in treating cough and sore throat, but not other symptoms.

“The most common and disturbing symptom of URTI in infants is fever, where honey has no benefit, but usual treatments – paracetamol and ibuprofen – are very effective,” says Eccles. Another symptom of the common cold or flu is congestion, and honey will not unblock the nose.

“Painkillers such as paracetamol, aspirin and ibuprofen would be my first treatment for colds and flu,” Eccles recommends, “followed by a hot, tasty drink.”

by **AMY BARRETT**

Amy is the editorial assistant at BBC Science Focus.

ANALYSIS

ASTEROIDS: HOW LIKELY IS IT THAT WE'LL BE STRUCK BY ONE?

It’s happened before, so what are the chances of another catastrophic collision with a space rock?

If you believe some recent headlines, an asteroid is threatening to derail democracy by blasting into Earth on 2 November – the day before the US elections. In reality, the space rock, called 2018 VP1, has only a 0.41 per cent (1 in 240) chance of hitting us. And even if it does, it’s only around two metres in diameter, so it’ll disintegrate in the atmosphere long before it’s had chance to ruffle any presidential hairdos.

CLOSE ENCOUNTERS

As its name suggests, 2018 VP1 was discovered in 2018, and it’s just one of around 23,500 ‘near-Earth objects’ (NEOs) being tracked by NASA’s Center for NEO Studies (CNEOS).

ABOVE Smaller asteroids aren't a threat, as they'll burn up in our atmosphere

NEOs are Solar System bodies which have orbits that bring them in close proximity to us (defined as coming within around 200 million kilometres of the Sun). A small number of NEOs are comets, but over 99 per cent are asteroids – rocky objects that are the leftover building blocks from the formation of the Solar System.

To work out the possibility of a NEO hitting Earth, CNEOS calculates the object's orbit around the Sun using data provided by observatories around the world. The more observations CNEOS has of a NEO, the better it can pin down the object's future trajectory.

The asteroids that pose the most risk are classed as 'potentially hazardous asteroids' (PHAs). These are calculated to come within around 7.5 million kilometres of Earth (approximately 20 times the distance from the Earth to the Moon) and are more than 140 metres in diameter. There are currently around 2,100 PHAs on NASA's books.

SIZE MATTERS

A 140-metre-wide asteroid could devastate an area the size of the UK, says Dr Paul Chodas, director of CNEOS, "but even small asteroids can cause significant damage". For example, the Chelyabinsk meteor, which took astronomers by surprise when it exploded above Russia in February 2013, was caused by an asteroid only 20 metres wide. The shock wave from the explosion was powerful enough to cause 1,500 indirect injuries, mostly due to flying glass from shattered windows.

The smallest asteroids, such as 2018 VP1, are extremely common, says Chodas. "A two-metre object hits the Earth every couple of months." But these aren't a concern, because they burn up in the atmosphere.

"The time between impacts gets exponentially longer as you go to larger asteroid sizes," says Chodas. Asteroids the size of the Chelyabinsk one are estimated to enter the Earth's atmosphere, on average, once every 80 years. "Once you go up to the size of PHAs – 140 metres – you can expect an impact, on average, only once every 20,000 years," says Chodas. And asteroids of the size that killed the dinosaurs – roughly 10 kilometres wide – happen around once every 100 million years. But Chodas says that these probabilities can't be used to predict when the next impact will happen. "It doesn't happen like clockwork," he says.

So what proportion of NEOs have we discovered? By looking for NEOs in the night sky – visible to telescopes as moving dots of light – and keeping tabs on which are newly discovered, and which have been spotted before, CNEOS scientists are able to estimate the total population of NEOs. Chodas says that they've so far found about 95 per cent of one-kilometre-wide asteroids and larger, and around ➤

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ABOVE
A trail from the near-Earth object that exploded over Chelyabinsk in 2013

40 per cent of asteroids measuring 140 metres wide and larger.

The Chelyabinsk NEO managed to sneak past telescopes because of its small size (the smaller the object, the fainter it is), and because it came from the direction of the Sun, which made it impossible to see against the glare. But the larger, more threatening asteroids can be seen further away, says Chodas, and this gives us more chance of spotting them in the night sky, hopefully providing us with "years or decades" of advance warning. This should give scientists enough time to prepare what's known as a 'deflection' mission, which aims to nudge the trajectory of the incoming asteroid so that it misses the Earth – by ramming a spacecraft into the asteroid, for instance.

There is still a possibility, says Chodas, that a large asteroid could take us by surprise if it was on an orbit that only brought it into close proximity with the Earth very rarely. In such a case, we might only have a few months' warning – too short for a deflection mission, but perhaps enough time for a 'disruption' mission, where the asteroid is blown up by, for example, firing a nuclear device at it.

"But we're driving down the chances of this happening by continually scanning the skies, and by making our telescopes more sensitive so that they can see asteroids that are farther out," says Chodas.

In the end, it all comes down to what we choose to worry about. The odds of a sizeable asteroid catching us unaware are so small, says Chodas, that there's plenty of other bad stuff out there that's more likely to happen to us. "The threat of an asteroid impact doesn't keep me awake at night," he says.

by **JAMES LLOYD**
James is the staff writer at BBC Science Focus.

COMMENT

MEDITATION: CAN IT DO MORE HARM THAN GOOD?

People use meditation to ease depression and anxiety. But can it actually worsen mental health?

Meditation has escaped both the religious cells of monks and nuns and the labs of scientists. An increasing number of people are using meditation apps to deal with mental health problems, such as depression and anxiety. Although there is no clear estimate of how many people are practising meditation, last year one single app had close to 40 million downloads.

But now my new study, which reviews over 40 years of the science of meditation and mindfulness-based therapies, suggests that these practices can also lead to negative effects in about 8 per cent of individuals – from increases in anxiety, depression and stress, to unusual experiences like hallucinations.

This sounds counterintuitive, given the thousands of scientific studies exploring the positive effects of meditation. But this study also indicates that scientists have been aware of these problems for a long time. In 1977, the American Psychiatric Association published a statement recommending that research on meditation should evaluate both its usefulness and its dangers. And ancient meditation manuals, like the Buddhist *Dharmatrāta Meditation Scripture*, likewise indicate that if meditation is not carried out properly, the mind can become unstable, restless or confused.

What does this mean to the millions of people using meditation to alleviate everyday stress and anxiety? Not to mention the increase in schools using meditation-based programmes with children. Is it possible that some of them may experience more harm than good? The new evidence from this and other recent studies shows that this is a real possibility.

Meditation techniques were developed to stimulate altered states of consciousness: to experience oneself in a different way, or even to challenge the 'ordinary' self. These experiences were not expected to always be pleasant or blissful. For example, there are meditation practices common to various religious traditions that recommend visualising one's death, or even finding a rotting corpse and focusing on its decomposition. This

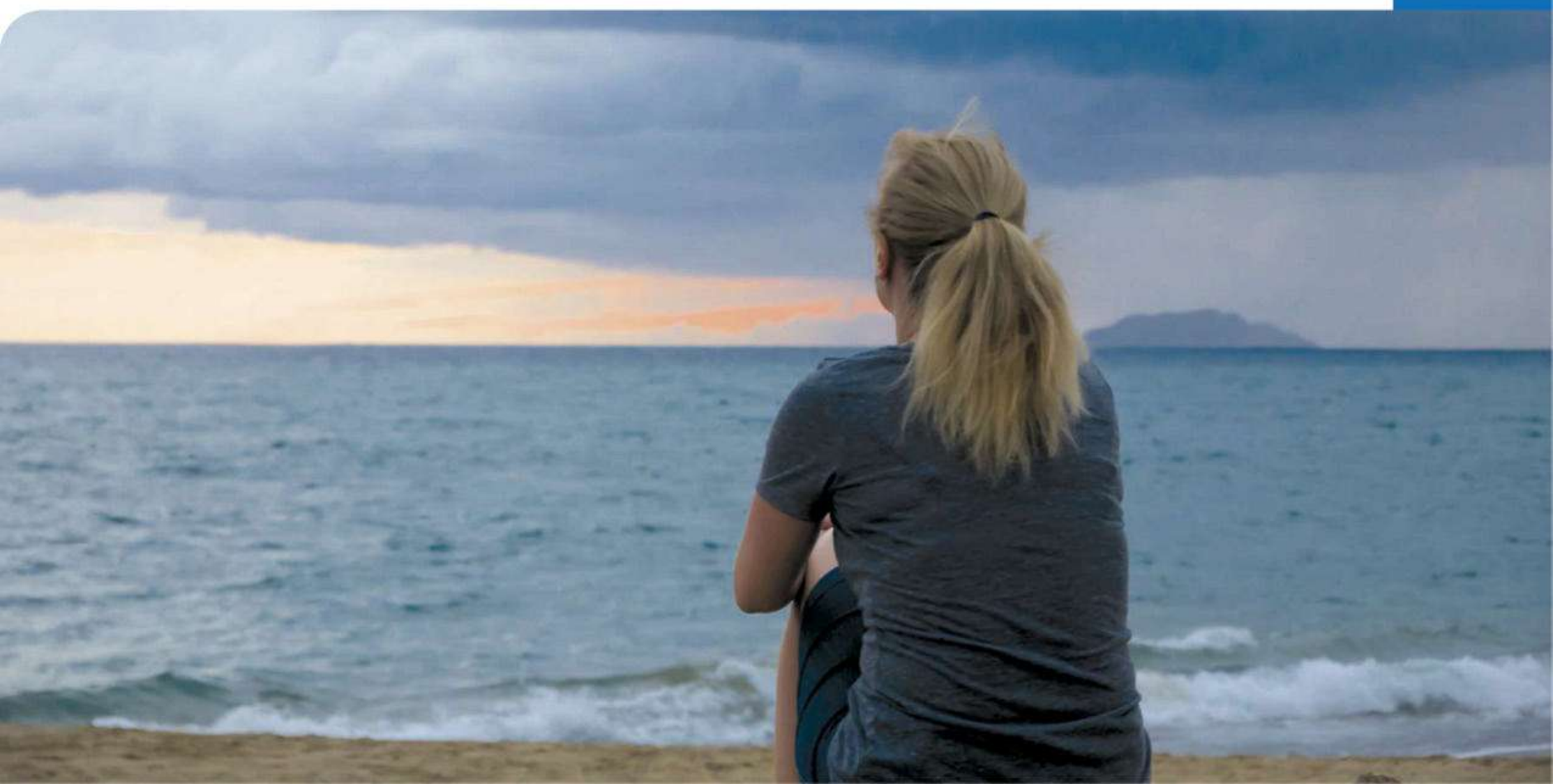
GETTY IMAGES X2

"Our understanding of the mind is still limited; the study of how we react to mind-altering practices like meditation is still in its infancy"

was expected to arouse fear and disgust, eventually leaving behind concerns about the world and oneself.

But people turning to meditation today are using it to enhance or heal the self: becoming more resilient, or less anxious and depressed. Are there conditions under which meditation is more likely to stimulate a negative experience? This new study reviews evidence suggesting that intensive meditation practice, such as that carried out in meditation retreats, sometimes increases the likelihood of negative events. On the other hand, it's not clear whether having a previous mental health problems will make you more at risk, which means that it could happen to anyone.

Some of this may sound confusing or alarming to many seeking wellbeing through meditation. But it needn't be so. Our understanding of the mind is still limited; the study of how we react to mind-altering practices like meditation is still in its infancy, and it's an important step in acknowledging the whole range of meditation effects, both positive and negative. This will motivate scientists to seek a more balanced understanding of when, for whom, and under what circumstances meditation can be beneficial, or harmful, and it will pressure commercial meditation/mindfulness apps and course providers to raise their ethical standards – at the very least, they should be obliged to inform the public that meditation is not a panacea, it doesn't work for everyone, and it may produce negative effects. **SF**



BELOW Meditation may not be beneficial for everyone

by **DR MIGUEL FARIAS**

Miguel is a psychologist at Coventry University's Centre for Trust, Peace and Social Relations.

SFP355

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These soundbars will help transform your living room into a home cinema p40

INNOVATIONS

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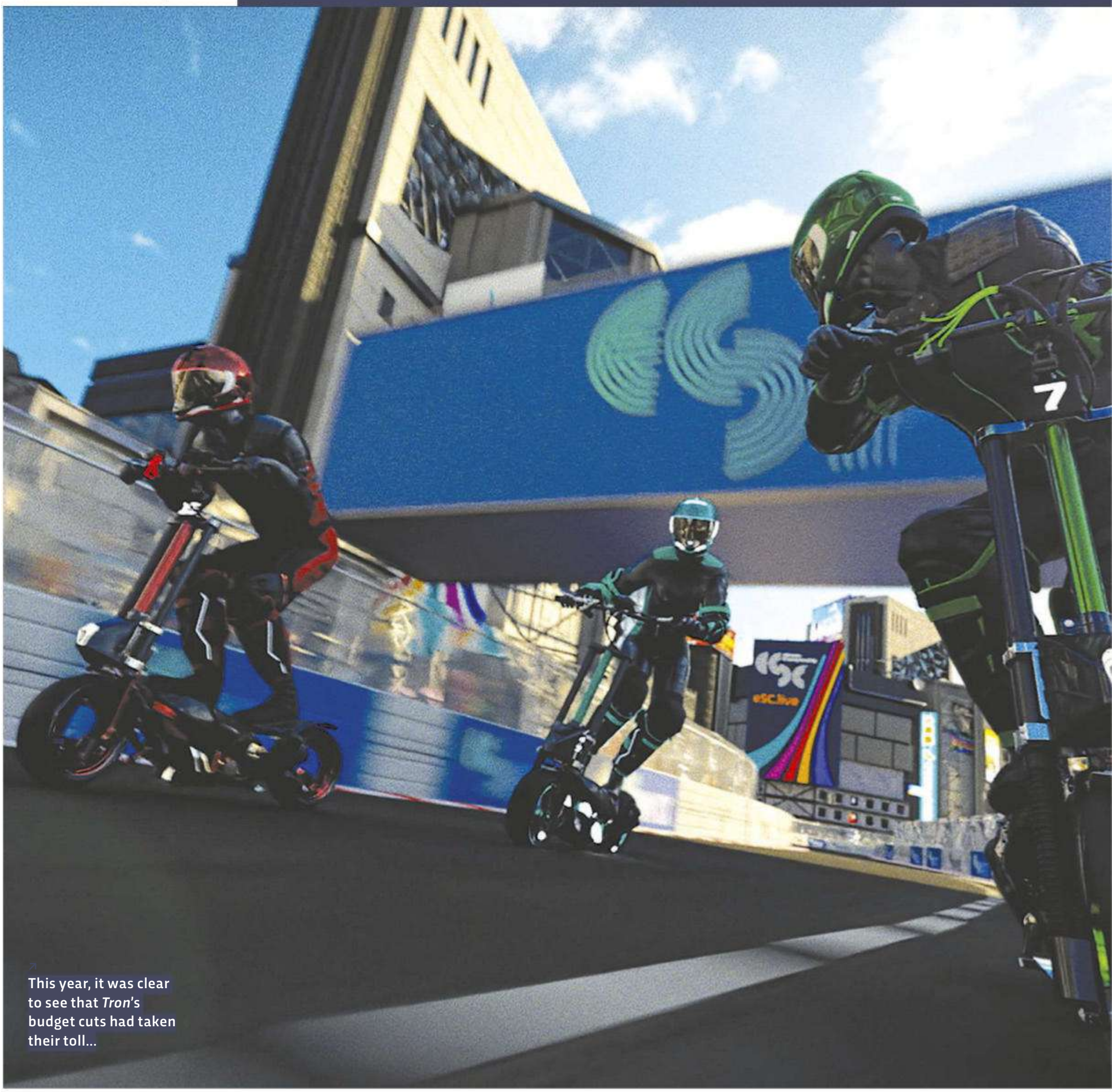


This year, it was clear to see that *Tron*'s budget cuts had taken their toll...

MORE ROBOT HELPERS' WACKY RACERS

Extreme E

This off-road, all-electric racing series will tour the planet's most remote places in 2021, spreading awareness of the changing climate. Lewis Hamilton has launched his own team that will take part in the series.

Andros Trophy

This series has grand ambitions of taking electric cars ice racing. It's a big sport in Scandinavia where new electric cars are being bought faster than anywhere else in the world.

MotoE

After a rocky start (a fire burned down all the bikes after a charger short-circuited), this new event rose from the ashes this year to become the motorbike equivalent of Formula E.

SCOOTERS

Super small, super fast

Renowned Formula 1 constructor Williams is developing high-speed, high-performance (completely nuts) scooters for the world's first Electric Scooter Championship, due to kick off next year

Tron-style electric scooters will feature in the Electric Scooter Championship (eSC), an event launched by a team of motorsports enthusiasts including Formula E champion Lucas di Grassi and ex-Formula 1 driver Alex Wurz. Details are yet to be finalised, but the group says the event will launch sometime in 2021.

The newly announced deal will see Williams Advanced Engineering (WAE) exclusively developing and supplying the eSkootr chassis, battery system and powertrain for the eSC's first two seasons.

"Williams Advanced Engineering has already demonstrated its pioneering approach to battery powertrain solutions in other motorsport series," says Iain Wight, the business development director at Williams Advanced Engineering. "The opportunity to further explore the sector with the eSkootr and eSC provides an opportunity for us to refine the packaging, ergonomics and systems required for deployment on a micromobility scale."

"SOME OF THE CORNERING AND ACCELERATION FIGURES WE'VE SIMULATED ARE REALLY QUITE EXTREME"

The eSC has been designed to "champion progressive micromobility policies and as an advocacy platform promoting smarter, cleaner and safer mobility in our cities," the founders say.

WAE has already begun development of a high-performance electric scooter prototype that they say will be capable of achieving speeds of more than 100km/h (60mph) and accelerate faster than most road cars. WAE will now continue to test their design on a series of newly developed micromobility race circuits, before supplying all entrants with finished models.

"Make no mistake this is a very high-performance model: some of the cornering and acceleration figures that we've simulated are really quite extreme. It's like nothing that's ever been seen before," says Wight. "It's clear that micromobility will play an increased role in the urban lives of millions of people, and the eSC provides a fantastic opportunity for manufacturers to develop and showcase new technology before it's brought to market."

ESKOOTR CHAMPIONSHIP X2

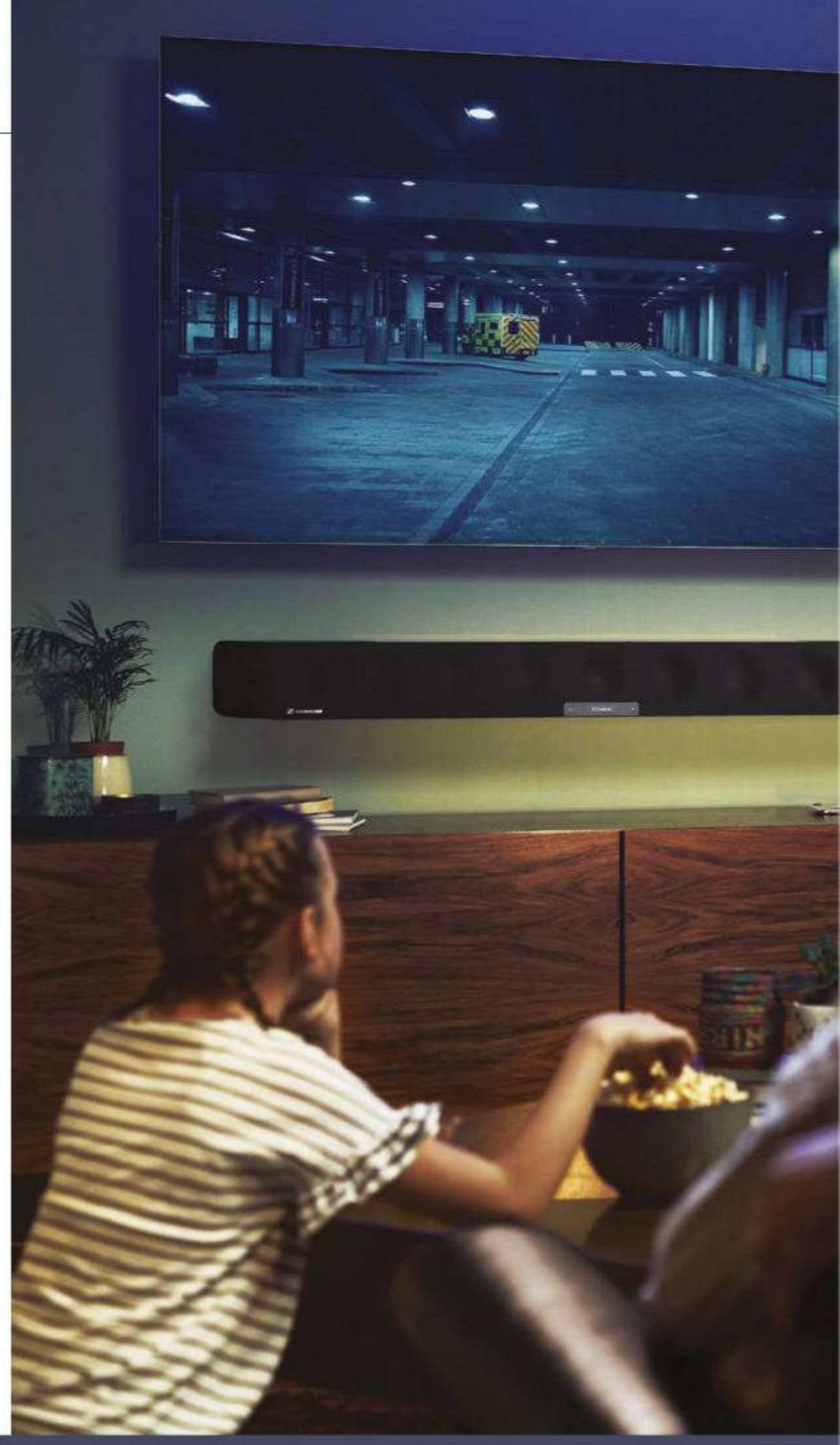
BUYER'S GUIDE

Home cinema soundbars

Winter is coming. It's time to get indoors and stay indoors (again), so why not give your home cinema system an upgrade? ***Verity Burns*** *chooses the best soundbars*

Soundbars are a fantastic way to improve the sound from your super-slim TV, without filling your living room with speakers. They'll give dialogue a boost in clarity, bump up the bass and add in the detail that goes missing when sound is left in the hands of the tiny speakers built into your TV.

But what started out as an easy way of improving your sound has slowly got more complicated as manufacturers have tried to make soundbars more and more capable. There's a host of new technology dedicated to simulating the surround sound you'd experience in the cinema, and at the top of the pile is Dolby Atmos – tech that's made its way out of the cinema and into your living room via the latest soundbars. Here's our pick of what's available.



What you need to know...

CONSIDER DESIGN CAREFULLY

Some soundbars are slim but come with a separate subwoofer; others are bigger and manage without. You'll need to think about the space you have before choosing one. For example, if you're putting it in front of your TV, check the soundbar's dimensions to make sure your stand has the width and depth to hold it. You'll also want to check your chosen soundbar doesn't obscure the TV.

If your soundbar comes with a sub, place it to the side of the TV as close to the soundbar as possible.

WHAT IS DOLBY ATMOS?

Atmos is a smart piece of tech from audio whizzes Dolby, which adds height to a surround sound experience. In a cinema, where it was first used, this would be carried out by as many as 64 speakers, placed around and above the listener. At home, soundbars attempt to recreate this experience by using angled drivers that bounce sound off your walls and ceilings. We are now seeing films released with Atmos soundtracks and even streaming services like Netflix and Amazon Prime support it.

GIVE YOUR ATMOS SOUNDBAR ROOM TO BREATHE

Atmos soundbars generally work by bouncing sound off your walls and ceiling to create a 3D surround sound effect. If you're spending the cash on the extra processing, you don't want to hide the soundbar away on a shelf inside a TV rack. If you do that, then the built-in height and side channels that fire sound upwards and outwards won't be effective. Give an Atmos soundbar some room to breathe for the best possible performance.

Soundbar jargon buster

As you hunt through the best options for turning your living room into a home cinema experience, you'll come across some of these words…

HDMI ARC/eARC
HDMI ARC (audio return channel) and the new eARC (enhanced audio return channel) allow you to send video and audio both 'upstream' and 'downstream' via a single cable – before, you needed two. This is the connection you'll need to use to connect your soundbar to your television via HDMI – it will usually be labelled on all kit from 2009 onwards.

CHANNELS
Home cinema sound is often discussed as channels, and written as 5.1ch or 7.1.2ch. These numbers refer to the number of individual channels of sound into which a soundtrack has been broken down. The first number refers to the number of surround channels, the second to the subwoofer channels and, when there's a third number, the number of height channels in an Atmos setup.

SUBWOOFER
A subwoofer is a separate bit of kit that deals with the lower bass frequencies. When used with a soundbar, it takes over when things get too low for the soundbar to manage. This will generally be explosions in action films, and kick drums and bass guitars in music.

IF YOU'RE GOING FOR ATMOS, MAKE SURE YOUR SETUP SUPPORTS IT

If you've just bought a new Atmos soundbar and connected it to an older TV, you might be disappointed to learn that your TV isn't capable of processing the Atmos sound. To bypass old telly tech, some soundbars will allow you to run your HDMI sources through the bar instead, but not all of them do. Do your research before buying to ensure you get the most from your setup.

KNOW YOUR INPUTS

You'll usually connect a soundbar to your television via an HDMI or optical digital connection. More affordable soundbars will usually only offer the latter, but if you have the option for HDMI, take it. HDMI will offer you the highest resolution sound decoding that your soundbar is capable of. You'll usually need to connect the soundbar to an ARC or eARC HDMI port on your TV for it to work though, so check that yours has one first.

MAKE THE MOST OF OTHER SOUNDBAR FEATURES

Many soundbars come packed with a bunch of features that make them really useful, even when you're not watching TV. Look out for Bluetooth connectivity so you can listen to your music and podcasts via the soundbar, high-res network streaming and even multi-room playback. You'll also find a growing number of soundbars with built-in voice assistants, so be sure to get all the features set up if you'll find them of use.

The options...

BEST FOR
CLEVER FEATURES

SAMSUNG HW-Q800T

PRICE: £699 | **CHANNELS:** 3.1.2 | **DIMENSIONS:** (HWD) 6 X 98 X 11.5CM | **WEIGHT:** 3.6KG | **SEPARATE SUBWOOFER:** YES (40 X 20 X 40CM, 9.8KG) | **BLUETOOTH:** YES | **WI-FI:** YES | **ATMOS:** YES

Samsung's mid-range soundbar is a feature-packed option that's accompanied by a wireless subwoofer to add some kick to the low end. This helps it to be slender enough to slide under the front of most TVs without issue, but it does come with brackets for wall mounting if you prefer.

Samsung's Acoustic Beam technology works wonders here, with 56 holes that act as individual speakers to direct sound high and wide from two upward-firing speaker arrays. The result is an impressive wall of powerful yet insightful sound that easily extends to the listening position and overhead.

When used with a compatible 2020 Samsung TV, the company's innovative Q Symphony feature can boost the sound even further, working with the TV's speakers to complement the soundbar performance and add more depth and height.

Still want more? Samsung offers a bolt-on wireless rear speaker package for expanding the virtual surround sound into a more physical one, which can really complete the experience and fill in the gaps that the soundbar alone misses out on.

SENNHEISER AMBEO

PRICE: £2,199 | **CHANNELS:** 5.1.4 | **DIMENSIONS:** (HWD) 14 X 127 X 17CM | **WEIGHT:** 18.5KG | **SEPARATE SUBWOOFER:** NO | **BLUETOOTH:** YES | **WI-FI:** YES | **ATMOS:** YES

Let's cut to the chase. This is one seriously expensive soundbar. It's also huge, as far as soundbars go. But if you've got the budget and the space, you won't find an all-in-one home cinema package that sounds better than this.

The sheer size of the Ambeo is what helps it sound so great. It's got 13 good-sized drivers that help to give it the edge. It's also got a generous selection of inputs, so you can choose what works best for you.

To get it sounding its best, it comes with a microphone and stand to help you perform a room calibration. This might sound complicated, but it's all automated and takes around a minute to complete. Once it's set up, the Ambeo's performance is as big and full-bodied as you'd expect. It excels at serving up detail and subtlety, with Atmos soundtracks among the most immersive we've heard.

BEST FOR
WHEN MONEY (AND SPACE) IS NO OBJECT

BEST OVERALL

SONOS ARC

PRICE: £799 | **CHANNELS:** 5.0.2 | **DIMENSIONS:** (HWD) 8.7 X 114 X 12CM | **WEIGHT:** 6.3KG | **SEPARATE SUBWOOFER:** NO | **BLUETOOTH:** NO | **WI-FI:** YES | **ATMOS:** YES

Offering up a hard-to-beat balance of features, design, ease of use and performance, the Sonos Arc is an easy product to love. There are few soundbars out there that do so much so well.

No matter what you're watching, it sounds absolutely superb. There's a stunning clarity to dialogue, a deepness to bass and stacks of detail across the frequency range. But when you listen to an Atmos soundtrack, you really hear the added breadth and depth you'd expect from a more immersive 3D soundstage, with sound effects that are placed precisely around and above you, delivered by the Arc's carefully angled drivers.

It'll fit into a wider Sonos multi-room system if you have other Sonos speakers, but it will also act as a superb sound system on its own for crisp, expressive music playback. There's even a choice of Amazon Alexa or Google Assistant built-in for voice control, plus the inclusion of Apple AirPlay 2 means you can stream to the Arc from any AirPlay-compatible iOS app. Its large size means you'll probably want a 55-inch TV or larger though, as it'll dwarf anything smaller.

SONY HT-G700

PRICE: £399 | **CHANNELS:** 3.1 | **DIMENSIONS:** (HWD) 6.4 X 98 X 10.8CM | **WEIGHT**: 3.5KG | **SEPARATE SUBWOOFER:** YES (39 X 19 X 41CM, 7.5KG) | **BLUETOOTH:** YES | **WI-FI:** YES | **ATMOS:** YES

BEST FOR
WHEN YOU'RE ON A BUDGET

Sony's budget Atmos soundbar does things rather differently from the rest of the options here, in that it leans heavily on audio processing to add that Atmos height on a budget.

Of course, all Atmos soundbars are using some form of technical trickery to put sound where it isn't, but there are no upwards firing drivers here – all of its channels face forward. Instead, the HT-G700 employs Sony's Immersive AE (Audio Enhancement) technology to do the Atmos heavy lifting, promising a 7.1.2ch performance from its 3.1ch set up.

Unfortunately, that bold claim doesn't quite play through in its performance, but the Sony is a lovely-sounding soundbar nonetheless. It adds clarity, depth and expression to a soundtrack, and pushes sound wider than the bar itself measures, but adds little by way of discernible height when compared with 'proper' Atmos soundbars.

For those on a budget, you'll get some impressively placed sound effects to the left and right, but you'll want to save a little longer for a more convincing Atmos experience.

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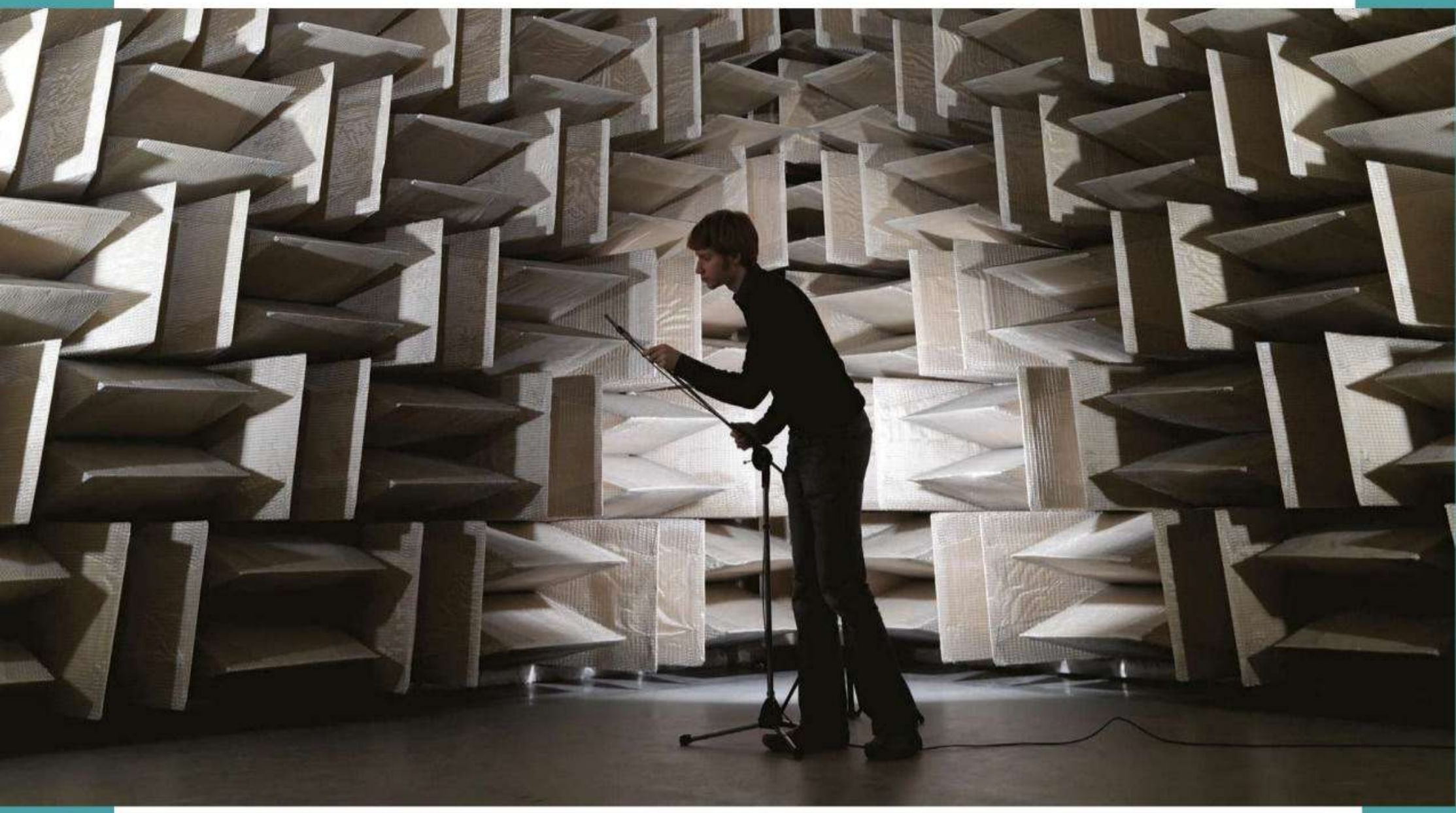
THE SCIENCE OF SOUND

Winter is the ideal time to give your audio an upgrade. But what do you need to consider when sorting out your sound system? This supplement explains all...



ALAMY

BLUETOOTH, AIRPLAY, CHROMECAST... DOES IT MATTER HOW I CONNECT TO MY WIRELESS SPEAKERS?

It depends on your priorities. All of these connections will ultimately allow you to play music from your device wirelessly, but there are pros and cons to each of them that might sway your decision. For a start, what device you own might make a difference. Bluetooth is pretty universal, and also arguably a lot more straightforward.

Google's Chromecast and Apple's Airplay both work using your home Wi-Fi network, whereas Bluetooth is a different, standalone technology. It works via a direct connection between wherever you have your music stored – such as your phone or laptop – and your speaker. That means Bluetooth is the thing to use outside of the house, as it isn't reliant on any other technology. However, if music quality is important to you, Wi-Fi speakers are better than Bluetooth. Chromecast pips AirPlay here, as it supports high resolution music (up to 24-bit/192kHz), while Apple's tech only supports playback to CD quality (16-bit/44.1kHz). Bluetooth is currently limited to around the same, but it will depend on your equipment as to whether it can manage it.

Other things to consider – Wi-Fi speakers generally have better range and also allow for multi-room playback with other compatible speakers in your home. Bluetooth is generally limited to a single device, though some companies are now allowing you to 'daisy chain' speakers together to play the same song across several speakers. Wi-Fi multi-room is more flexible – you can play different songs on different speakers.

THIS SUPPLEMENT IS SPONSORED BY FLARE LONG LIVE EARS qobuz

WHAT DOES AN AMPLIFIER ACTUALLY DO?

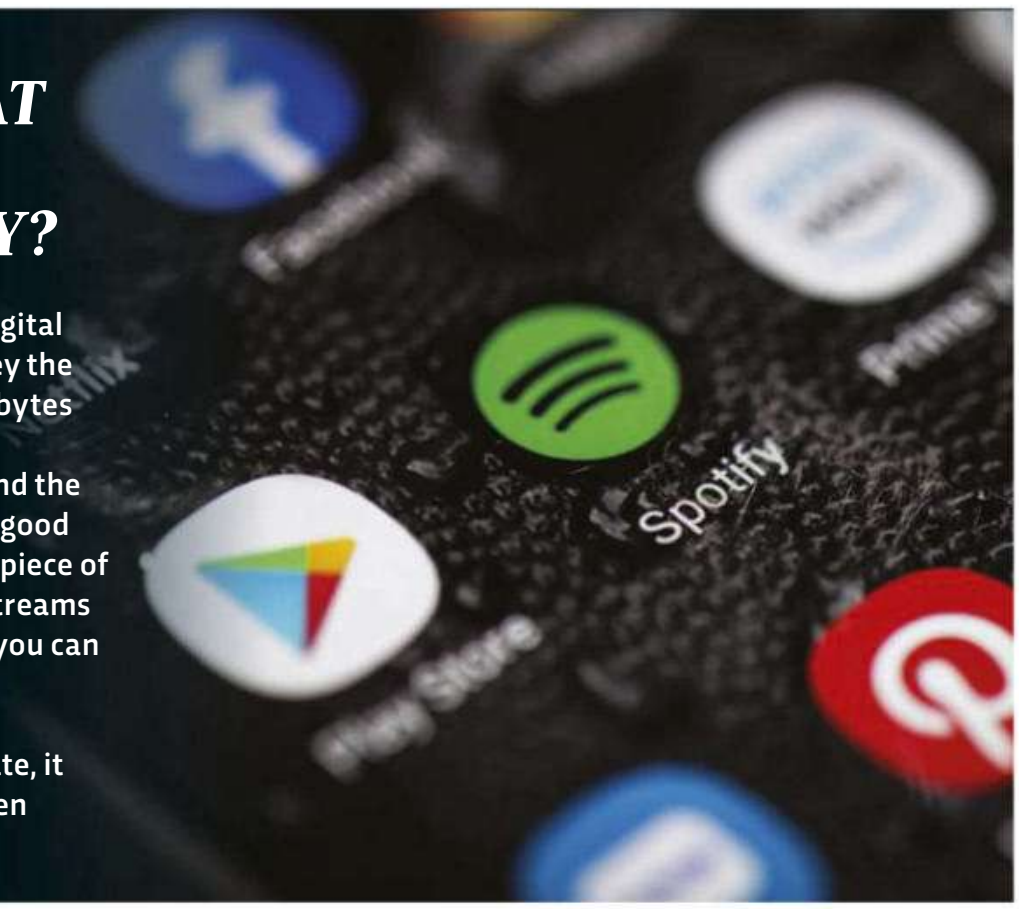
An amplifier takes an input signal from a source, such as a laptop, turntable or CD player, and creates a larger copy of the original signal before it's sent to the speakers. It gets the power to do this from your mains electricity, which is sent directly to the power supply within the amplifier. Here, it's converted from an alternating current to a direct one, which only flows in one direction, and is sent on to the transistor. The transistor works like a valve, and determines the amount of current that flows through the circuit at any time. It bases that decision on the size of the input signal from the source. That means a large signal will cause the transistor to allow more current to flow, which in turn creates a greater amplification. The volume control is the final bit of the puzzle, which decides how much of this current is passed through to the speakers.

WHAT'S A BITRATE, AND WHAT DO I NEED TO KNOW TO UNDERSTAND MUSIC QUALITY?

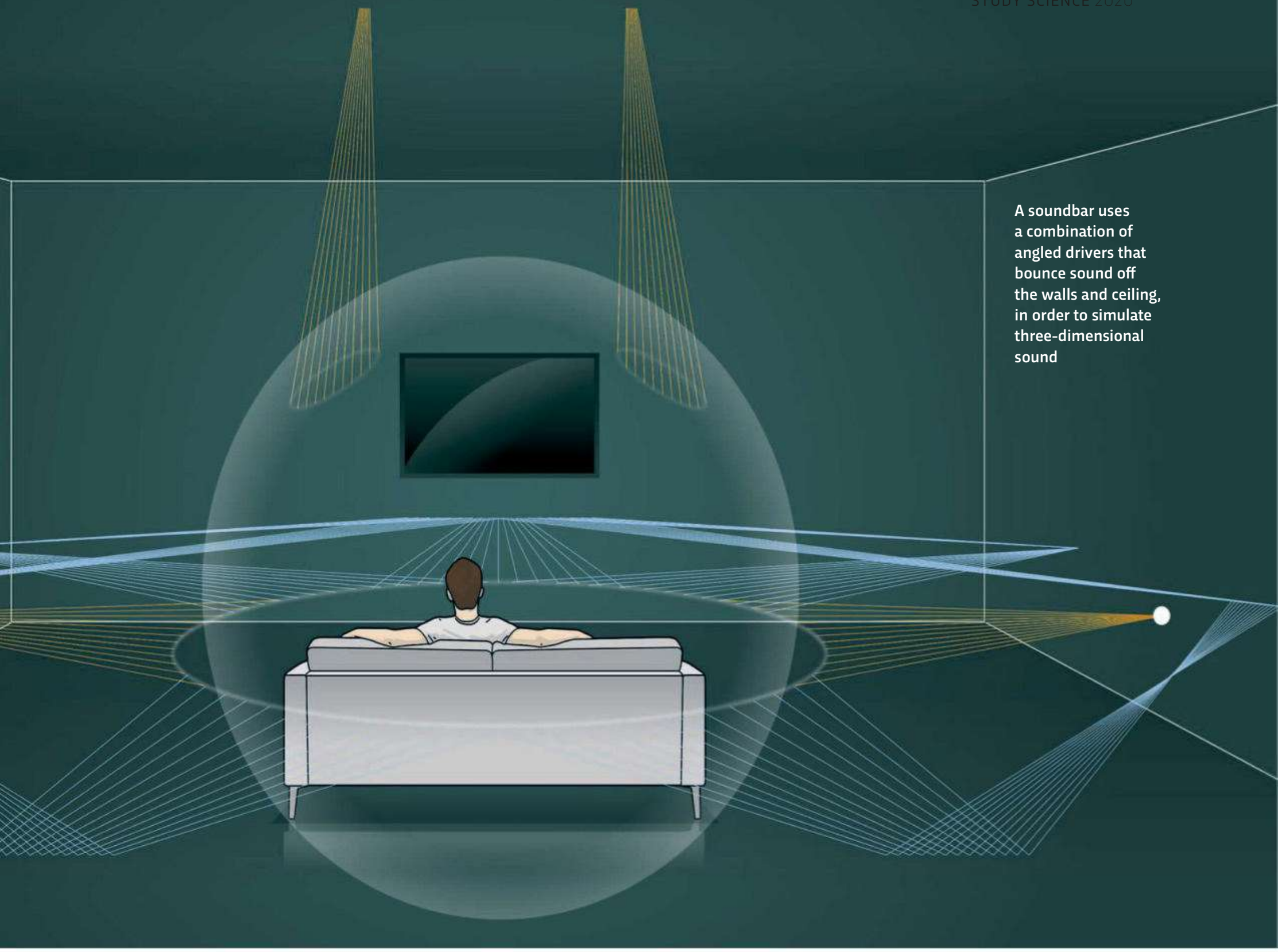
Bitrate refers to the amount of bits – or the amount of data – a digital audio file contains per second. It's most commonly used to convey the quality of compressed audio formats, such as MP3 or AAC, in kilobytes per second (kbps).

The higher this number, the more information that file holds and the less compressed it is. Assuming the source it originated from is a good one, more information generally translates to a better-sounding piece of music. Spotify Premium streams at 320kbps while Apple Music streams at 256kbps. It will depend on the kit you are using as to whether you can hear a difference between the two, but the Spotify streams are, technically at least, better quality.

By comparison, if you were to break down CD quality into bitrate, it would be 1,411kbps, which shows the difference in quality between compressed and uncompressed (lossless) music.



ALAMY X2, ACUTE GRAPHICS



A soundbar uses a combination of angled drivers that bounce sound off the walls and ceiling, in order to simulate three-dimensional sound

SOUND TRAVELS THROUGH 20°C AIR AT 344M/S. IN HOT CONDITIONS IT TRAVELS FASTER

HOW DOES A SOUNDBAR SIMULATE THREE-DIMENSIONAL SOUND?

Just like in a traditional surround sound setup that requires separate speakers all around your room, soundbars capable of 3D sound will have several different audio channels, each of which plays a different part of a film's soundtrack. You can tell the soundbars that support this as they will be described as being '5.1.2 channel', or similar. The first number is the number of traditional surround channels that are supported, which is usually five, seven or even nine. The second is the number of subwoofer channels for handling the lower frequencies, while the last number refers to the number of upwards-firing channels, which are the ones that give you that '3D' effect.

Each of these channels will need to be represented by one speaker at least, but some soundbars may even have several on the job – particularly on the centre channel, which handles dialogue.

To simulate the 3D sound effect, soundbars use a combination of angled drivers, to bounce sound beams off the walls and ceiling, and clever processing. This processing makes subtle adjustments to volume, timing and frequency to further add to the illusion of sound coming from places it actually isn't.

These soundbars usually run an automatic setup so they can understand the layout of your room and adjust where they direct the sound beams accordingly. Even so, the shape of your room will still likely determine how effective the results are.

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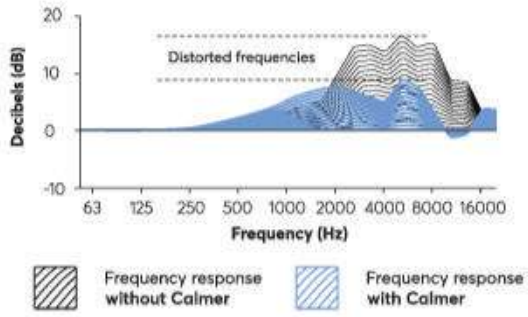
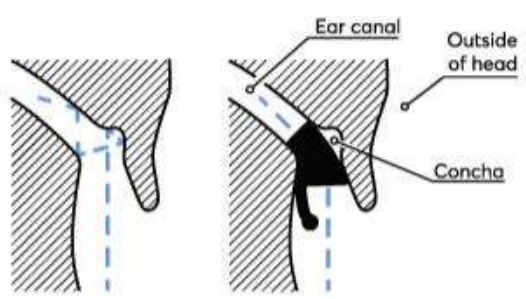
FULL DISCLOSURE: Tinnitus was never an intended benefit of Calmer. Tinnitus is a complex and very individual problem and Calmer doesn't help everyone who suffers but some people report noticing a huge improvement, while others have reported none.





"ONE OF THE THINGS I'VE NEVER REALLY EMBRACED IS THE USE OF HEADPHONES WHEN LISTENING TO MUSIC.
THAT IS UNTIL NOW. NOW I HAVE A PAIR OF CALMER... I AM NO LONGER JUST HEARING MUSIC - I CAN ACTUALLY LISTEN TO IT."

Gary Langan: Producer, Engineer, Co founder of Metropolis studios, and a member of the Art of Noise

ABOVE: Frequency response of the human ear and how it is changed when wearing Calmer. This change is due to Calmer guiding sound into our ear more efficiently, by-passing the Concha.

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HOW DO WE CONVERT AUDIO FROM ANALOGUE – TO DIGITAL – TO ANALOGUE?

All sound is made up of a continuous analogue soundwave, but digital kit like computers, phones and CD players can't process sound in its analogue form, which means it has to be converted into a digital signal – a long chain of numbers, made up of ones and zeros – to be stored and processed digitally. This is done using an analogue-to-digital converter (ADC), while a digital-to-analogue converter (DAC) is used to reverse the process at the other end.

An ADC works by first taking 'samples' of the soundwave, which measure its amplitude at regular intervals. In order to put a numerical value on these samples, the amplitude is split into levels along the vertical axis. The number of levels depends on the bit depth, which is determined by the resolution of your ADC. Most commonly, they are 8-, 16- or 24-bit. The greater the bit depth, the more accurate the signal will be, because every sample measurement is converted to the binary value that intersects it on the waveform. If it falls between two binary values, it will be rounded up or down accordingly. This is called quantisation, and is how the digital signal deviates from the analogue. However, the higher the resolution, the more binary values there are for samples to be converted to and the less quantisation occurs. With an 8-bit ADC, there are 256 possible binary values. With a 16-bit ADC, there are 65,536.

As for DACs, they decode the binary digital signal to rebuild the analogue wave, smoothing out the 'steps' that are added through quantisation in the process. This is called interpolation, which looks at two points and approximates the values between them in order to fill in the gaps.

DO WIRES MATTER?

This is a controversial one, so let's stick with the science. When it comes to digital cables like HDMI, no. A cheap cable will do the same job with ones and zeros as a pricey one.

For analogue cables, like speaker wires or interconnects, there is more evidence to suggest they can have some impact on sound, if you have a system transparent enough to hear it. Until then, spending on other areas of your setup first is likely to create a bigger impact – though included freebie cables are always worth upgrading.

HUMANS CAN HEAR SOUNDS AT FREQUENCIES OF 20HZ TO 20,000HZ

ALAMY X2

DOES VINYL REALLY SOUND BETTER?

Well, that all depends on what you're comparing it to. Does it sound better than an MP3? Absolutely – vinyl wins this one hands down.

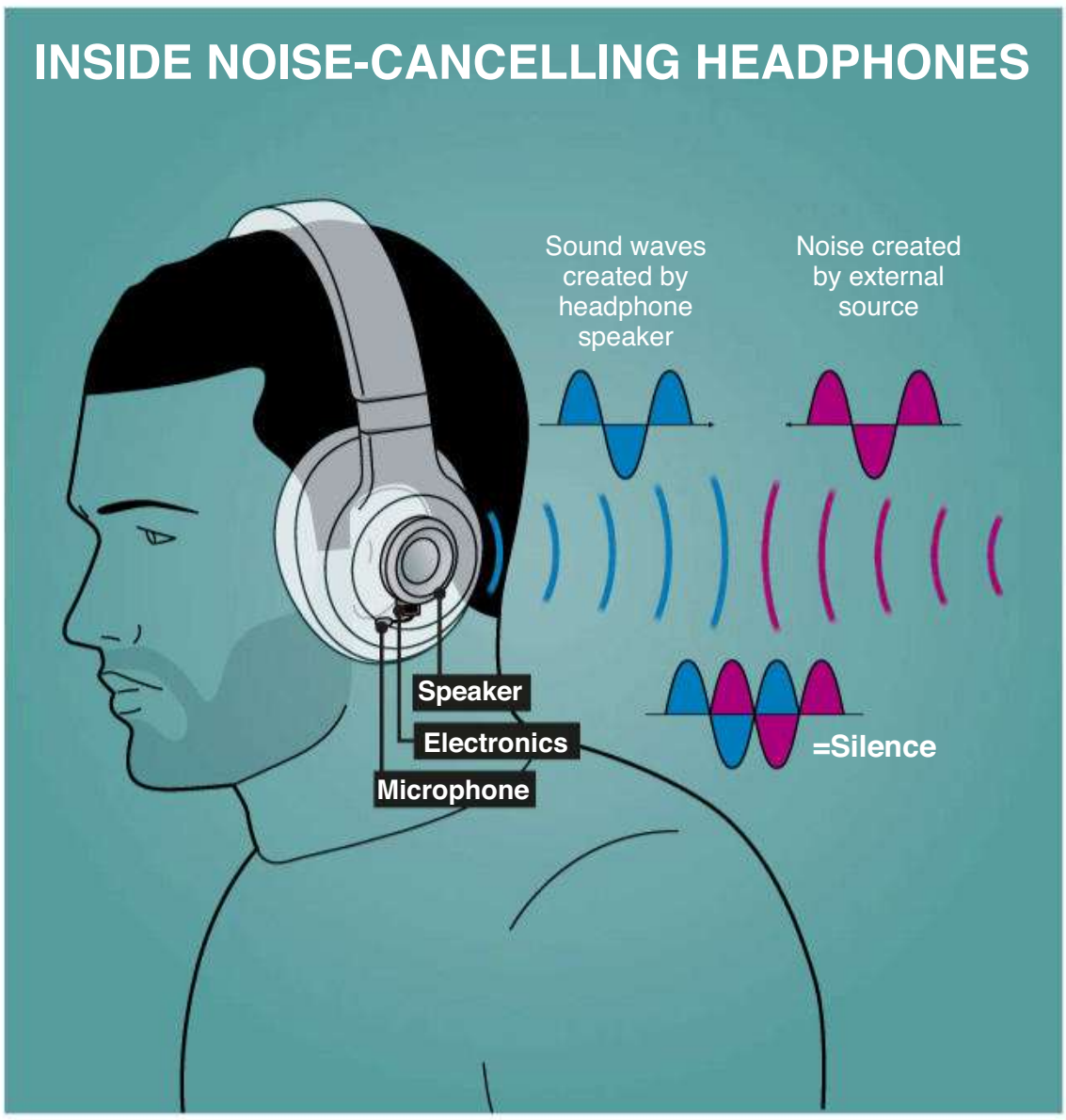
However, compared to a CD? That's more tricky. Vinyl fans will argue that as it is an end-to-end analogue format, from the recording and pressing to playback, that it more closely reproduces what the artist originally played in the studio.

Digital music works much differently. As digital kit cannot read analogue soundwaves, they are translated into a digital signal and back into analogue again, meaning some information is lost or approximated in the process. With vinyl, every single part of the analogue wave is captured in those grooves, making it the only true lossless format.

However, there are inconsistencies. Not just the wear and tear of vinyl that will degrade playback quality over time, but the physical limitations. For example, a longer album will require slimmer grooves, creating a quieter sound and more noise as the needle moves through them.

An album is also likely to sound worse at the end than at the beginning as the needle speed changes to compensate for the change in circumference. And that's before you account for poor pressings and the fact that many modern vinyl records are actually cut from digital masters anyway – so they are no longer a pure analogue signal at all. Will they all of a sudden sound better for being on vinyl? Of course not. But they will sound more 'vinyl'.

And therein lies the answer. Vinyl has its own, distinctive sound, filled with surface crackle, pops and distortion that people love. Calling it 'better' probably isn't accurate, but there's certainly nothing else like it.



HOW DO NOISE-CANCELLING HEADPHONES CANCEL SOUNDS?

Noise-cancelling headphones cancel out unwanted sound by creating an opposing sound wave that mimics the noise you want to get rid of, but just 180° out of phase. This means that when one sound wave is at its highest peak, the other is at its lowest, effectively cancelling each other out. This is known as 'destructive interference'. To make this happen, several components are required to work together. First, there is a microphone on the earcup to listen out for annoying external sound. When any such noise is registered, the microphone reports back to the noise-cancelling circuitry with the frequency and amplitude of the incoming sound wave.

With this information, the 'out-of-phase' sound is created and then fed into the headphone speakers, along with the music you're playing. This masks the external noise without being audible itself or affecting the music you're listening to.

It works best with lower frequencies, like transport noise, and while it can't erase unwanted sound entirely, around 70 per cent of ambient noise can be blocked using this method. Just remember to keep the headphones' battery charged – active noise cancellation requires power to work.

by VERITY BURNS

Verity has been writing about tech for over a decade. She has particular experience in audio and TV reviews. At parties, you'll find her in the living room, recalibrating terrible TV settings.

GETTY IMAGES, ACUTE GRAPHICS

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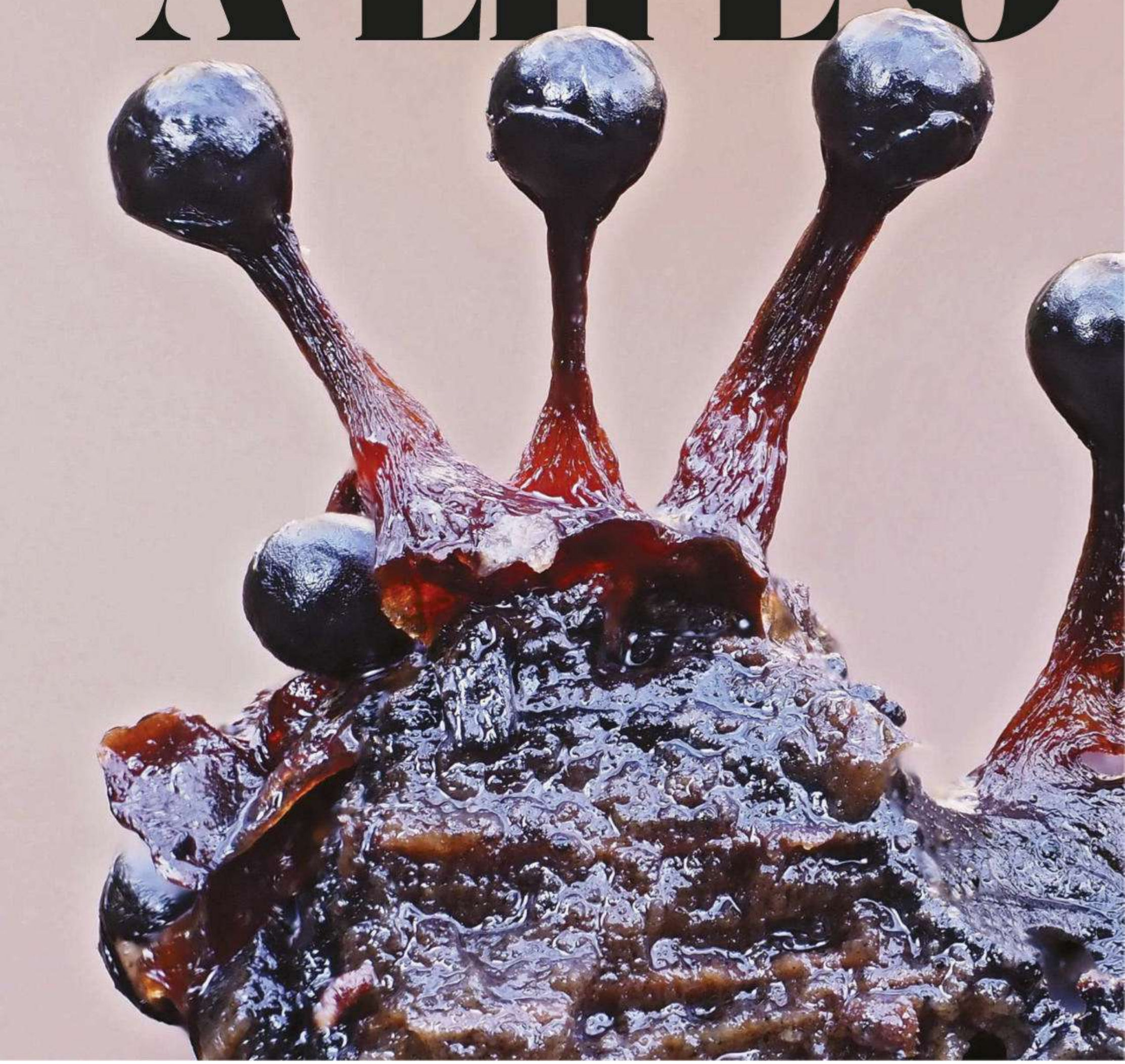


F SLIME

Do you need a brain to solve puzzles? Not if you're a slime mould. These single-celled organisms can learn, navigate mazes and perhaps help us gain a deeper insight into the structure of the Universe itself...

WORDS **JULES HOWARD**
PHOTOS **ANDY SANDS/NPL**

The shiny, fruiting bodies of *Metatrichia floriformis* look like tiny berries

The Paris Zoological Park opened an exhibit like no other in October 2019. Inside the glass tank, to the amazement of passers-by, was an organism that could think yet had no brain. That could remember without experiences. That could build information networks with an efficiency unmatched in the history of the human species. It was a slime mould. They called it 'Le Blob'.

Slime moulds rarely feature in pub quizzes or nature documentaries, so why should we care about them? Let's start with the basics. First, slime moulds aren't just one kind of organism, but are rather a collective of organisms that closely resemble amoebae. Most slime moulds live out their lives as single-celled microorganisms, so small that they can't be seen with the naked eye. But when they're ready to reproduce, they can scale up in size to form fruiting bodies, or 'sporangia', which release spores into the wind in a way that parallels fungi, a group to which they are not closely related. Some of these spores will develop into single-celled slime moulds, beginning the cycle anew.

Slime moulds come in a range of colours, and they can be found in woodlands throughout the world, in soils, on the branches or trunks of dead trees, and in leaf litter. They feed upon other microbes such as yeast and bacteria. Some slime moulds are beautiful, forming ornate, tree-like sporangia. Others – like the 'dog vomit' slime mould – are somewhat less attractive.

All of the slime moulds on these pages were captured by UK-based photographer Andy Sands, who says he spends months searching for them in the woods close to his Hertfordshire home. "The fact that you can find the same species pretty much anywhere on the planet is fascinating to me," he says.

SLIME AND SLIME AGAIN

To scientists, one particularly interesting group is the so-called 'plasmodial' slime moulds, which have evolved a spectacular way to find food. By continually replicating their genetic material without dividing into new cells, species of this group are able to become an enormous super-cell that stretches more than 10 metres across its surroundings. According to Dr Audrey Dussutour, a slime mould expert at the Centre for Integrative Biology in Toulouse, France, it's at this stage of its life cycle that a plasmodial slime mould is best described as a 'blob'.

Dussutour's favourite plasmodial slime mould is *Physarum polycephalum*. This species is the star of the Paris exhibit, and it's fast becoming the fruit fly of slime mould research. Its Latin name translates as 'many-headed slime' for its habit of sending out finger-like tendrils that can grow by about one centimetre ➤

ABOVE Dog vomit slime mould (*Fuligo septica*) on dead wood

TOP RIGHT Close-up of the massed fruiting bodies (sporangia) of *Ceratiomyxa fruticulosa*

ABOVE RIGHT *Physarum album* in its reproductive phase, with sporangia

“Species of this group are able to become an enormous super-cell that stretches more than 10 metres across its surroundings”

each day in search of food. In the last 10 years, this species has proven capable of a swathe of impressive talents. Most famous is its ability to find its way around a maze: as the slime mould moves through the maze on the lookout for food, it is able to sense the trail of slime that it's left behind, allowing it to avoid previously explored areas.

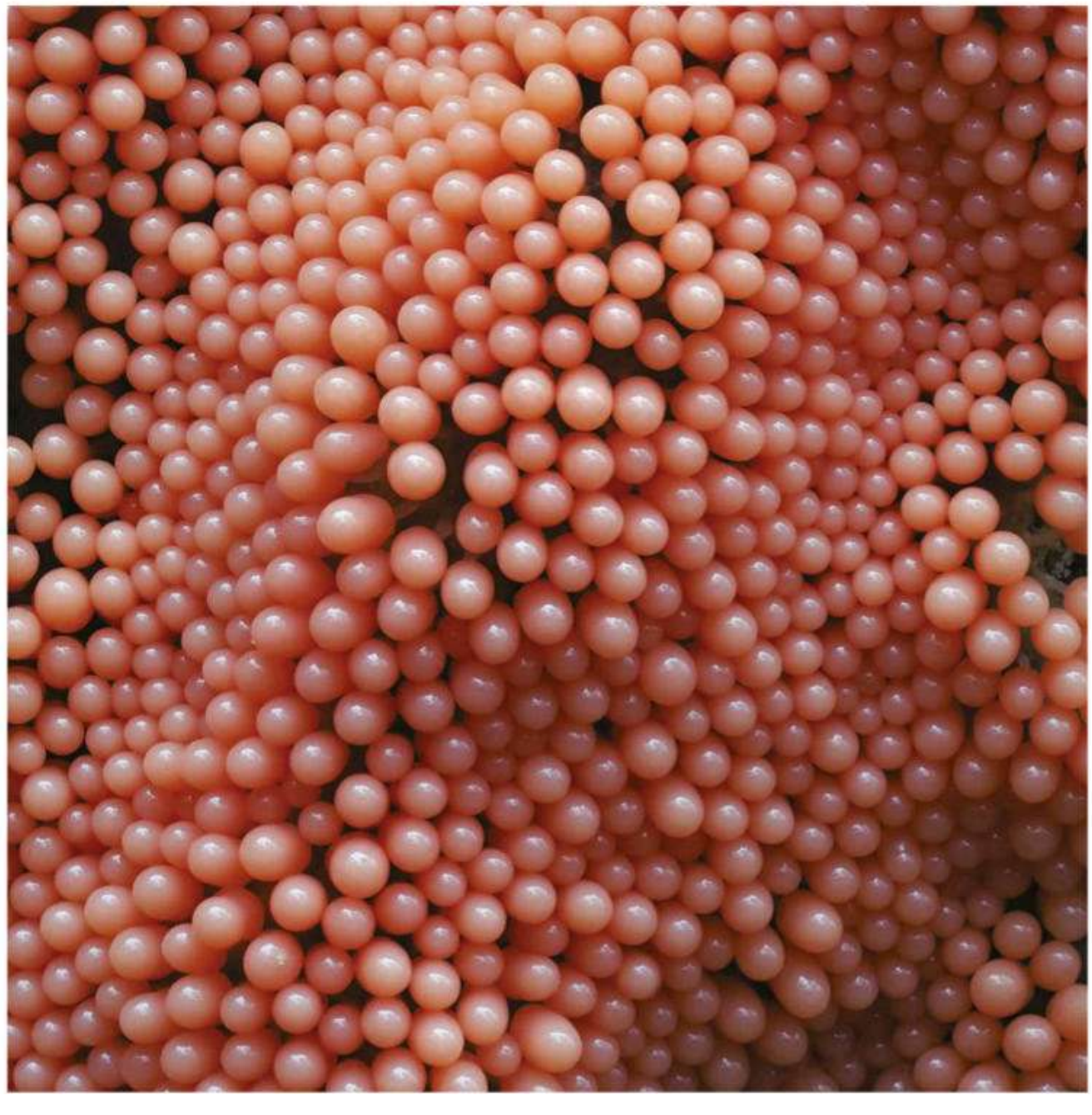
Incredibly, research by Dussutour and her colleagues shows that *P. polycephalum* is also capable of a primitive style of learning. Normally, when one of the slime mould's tendrils encounters a negative stimulus, such as salt or caffeine, it slows its advances, preferring to focus its growth elsewhere. But if it discovers that it can reach a food source by travelling through the stimulus, it learns, over time, to keep going to get its reward. The species habituates to threats, in other words, and learns that a little bit of salt or caffeine won't kill it. One of the interesting things about this habituation behaviour is that, rather like a good piece of advice shared between friends, it can be passed on by fusing with other slime moulds that have never encountered the risk. Even more interesting is that this behaviour resides in the slime mould for many weeks, even if the blob goes into a dried-up, hibernation-like state.

"Slime moulds illustrate that even simple organisms can exhibit behaviours usually encountered in animals with brains," says

LEFT *Physarum polycephalum* on the move as a single super-cell

RIGHT *Arcyria ferruginea* in its reproductive phase. Fossils tell us that slime moulds have existed relatively unchanged for more than 100 million years

"Even simple organisms can exhibit behaviours encountered in animals with brains"



Dussutour. "They encourage us to take another look at single-celled organisms."

P. polycephalum's efficiency for homing in on food, using chemical taste buds that direct its movement, has begun to pique the interest of town planners and transport engineers. By arranging the slime mould's favourite food (porridge oats) in a Petri dish in a way that replicates the locations of towns and cities, researchers can gain insights into how best to lay out routes. For instance, we know that Tokyo's railway system is one of the most efficient in ➤

“Sex, slime, society – the more we look into the blob, the more we see ourselves reflected in its goo”

LEFT *Arcyria denudata* in its reproductive phase. Without slime moulds, the world’s soils and forests would become overrun with bacteria in a matter of days

ABOVE The false puffball (*Enteridium lycoperdon*) is a common species found in the UK. It can be seen in its reproductive phase as a white swelling on dead trees

the world. Why? Because, when oats are used to map out a scale-layout of the city’s railway stations, the tendril-like pathways that the slime mould grows between food sources match up clearly against the city’s actual railway network. On the other hand, we can say that the USA’s road network is one of the worst. The UK’s road network is somewhere in-between. For example, slime moulds tend to grow an M6 on the eastern side of England, heading north via Newcastle rather than through the Lake District.

Now, this simple methodology is even attracting the interests of cosmologists attempting to fathom the whereabouts of dark matter in the Universe. Algorithms generated by observing the ways in which slime moulds grow connections between food sources have provided a useful model for scientists to explore how dark matter connects galaxies in a complex spaghetti of interacting filaments. Again and again, slime moulds have the answer.

BREAKING THE MOULD

In all, there are some 900 known species of slime mould, but there are likely hundreds more waiting to be discovered, along with their weird and wonderful behaviours. One intriguing finding is that some species ‘farm’ bacteria in a similar way to how leaf-cutting ants farm fungus. When colonising new areas, the slime mould carries with it a species of bacteria that it cultivates in its new home, later feeding upon it. The sex lives of slime moulds also deserve a mention. Whereas animal sex cells come in male and female forms, slime moulds have a swirling mass of additional types of sex cell – giving them around 720 sexes in total. As long as two different types of sex cell meet, fertilisation can occur.

Sex, slime, society – the more we look into the blob, the more we see ourselves reflected in its goo. So enjoy the slime moulds on these pages. Look out for them in your local patch. Vive Le Blob. Because each one is its own charming exhibit. SF

by JULES HOWARD
Jules is a zoology expert and science writer. His latest book is Encyclopedia Of Insects *(£14.99, Wide Eyed Editions).*

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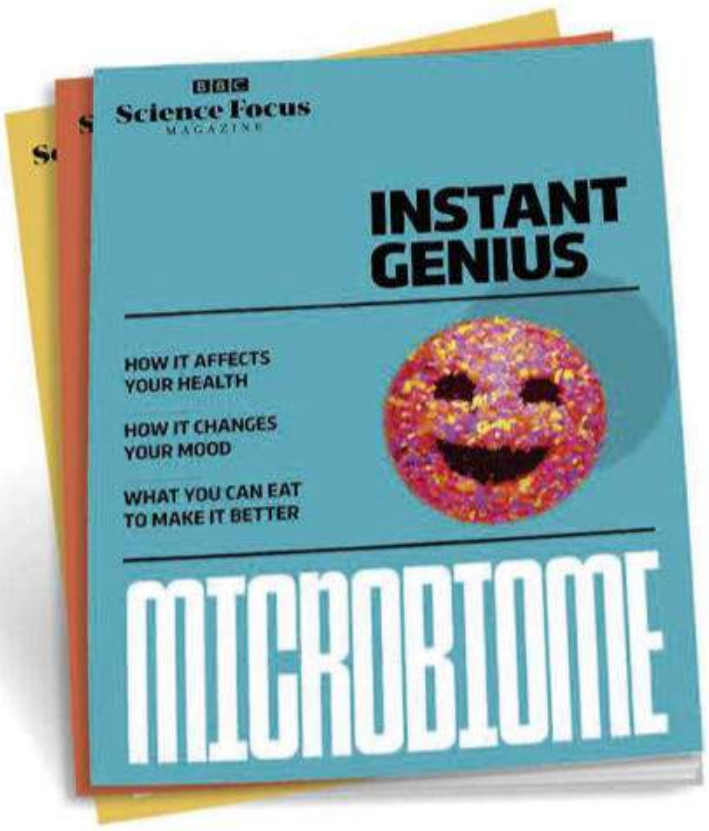
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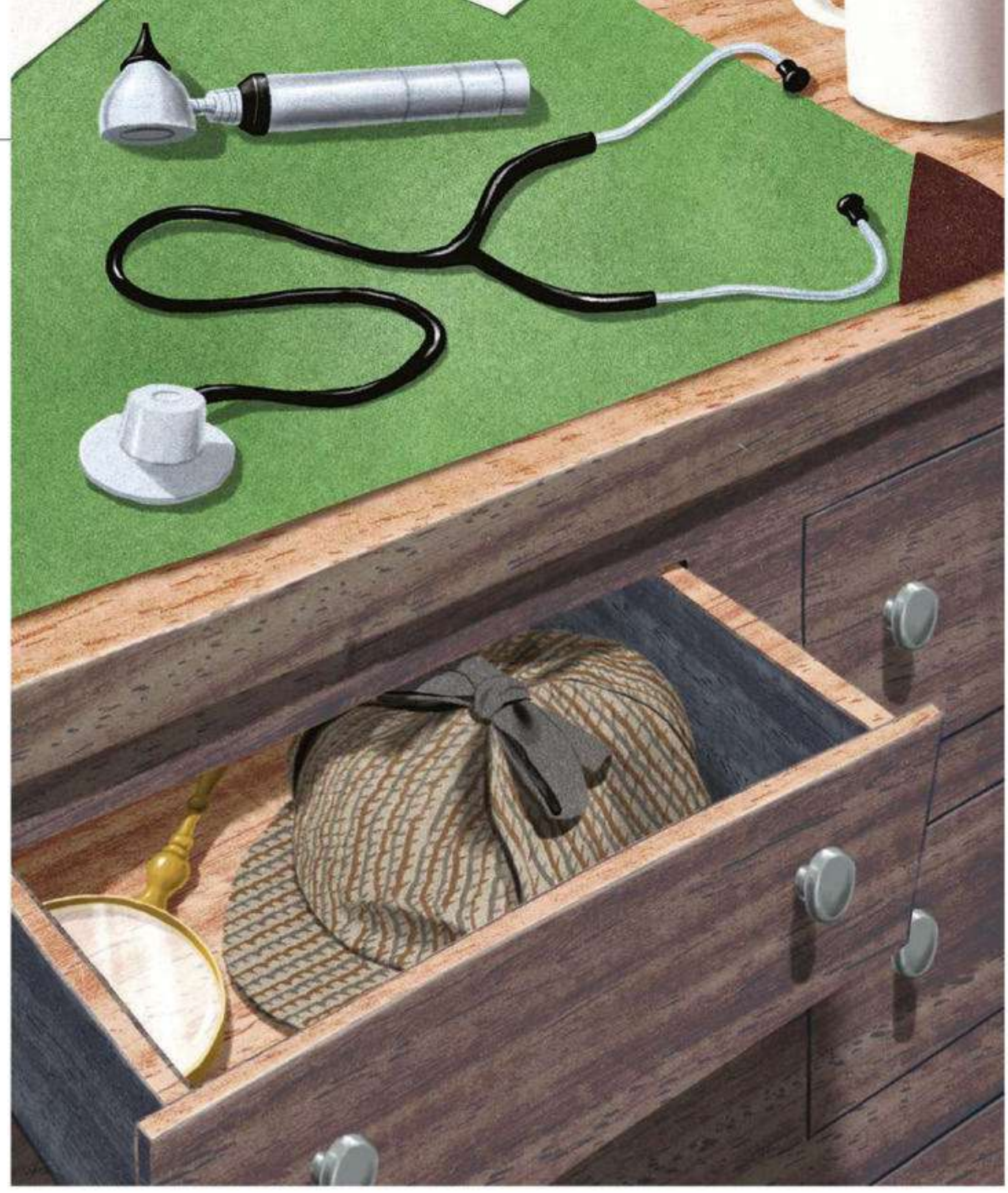
COMMENT

THE DIAGNOSIS DETECTIVES

Sometimes, doctors have to unleash their inner sleuths in order to solve tricky cases



One of the most famous fictional detectives of all time is Sherlock Holmes. Holmes uses his extraordinary skills of observation to crack seemingly impossible cases. What you might not know is that Sir Arthur Conan Doyle, the creator of Sherlock Holmes, studied medicine at the University of Edinburgh before becoming a writer, and based his character – at least partially – on a former university teacher called Joseph Bell. Bell was, apparently, particularly brilliant at spotting things other doctors had missed.

The ability to use observation and deductive reasoning to help make an accurate diagnosis is at the heart of medicine. It is also at the heart of my new BBC series, called *Diagnosis Detectives*. In this series, we're bringing together 12 of the UK's leading medical experts to help people whose symptoms have baffled other doctors. Each of our specialists is a leading light in their field. The idea is that by combining their expertise and, where appropriate, bringing in cutting-edge technology, we should be able to give our patients the answers they so desperately crave.

As you can imagine, this was a difficult series to make, so all credit must go to the production team who pulled it together. First, they had to find suitable patients, who had a genuine, mystery illness and who were in great need. Then we had to hope that our crack team of experts would be able to make a diagnosis.

"The ability to use observation and deductive reasoning is at the heart of medicine"

Let me give you an example of what our experts were up against. At the beginning of the programme, we met Paul, a 75-year-old from London. Eighteen months ago, he woke up with a swollen, puffy right eye. He went to see his GP, who did a test for conjunctivitis, that was negative. Next, he was referred to Moorfield's Eye Hospital. They diagnosed inflammation of the eyelid, and he was given topical creams, as well as oral antibiotics. The swelling went away but then came back with a vengeance.

Our experts wondered if it could have been triggered by something he'd bought, a new shampoo or a change of washing powder? Our rheumatologist noticed that he had vitiligo – essentially the loss of skin pigment in some areas. Could this be an important clue, a sign of some underlying inflammatory process? Or could it be something more sinister, like lung cancer?

The number of possible diagnoses began to grow, and any life-threatening diseases had to be rapidly excluded.

In the end, the experts were able to establish that it wasn't cancerous and it wasn't anything contagious. In fact, the final diagnosis was that he had sarcoidosis, a rare condition that causes small patches of red and swollen tissue to develop, particularly in organs like the lungs and skin. It is not curable, but it is certainly treatable. So, another case solved, and a sense of relief for the patient. SF

MICHAEL MOSLEY

Michael is a writer and broadcaster. You can catch up with *Diagnosis Detectives* on iPlayer. His latest book is *Fast Asleep* (£9.99, Short Books).

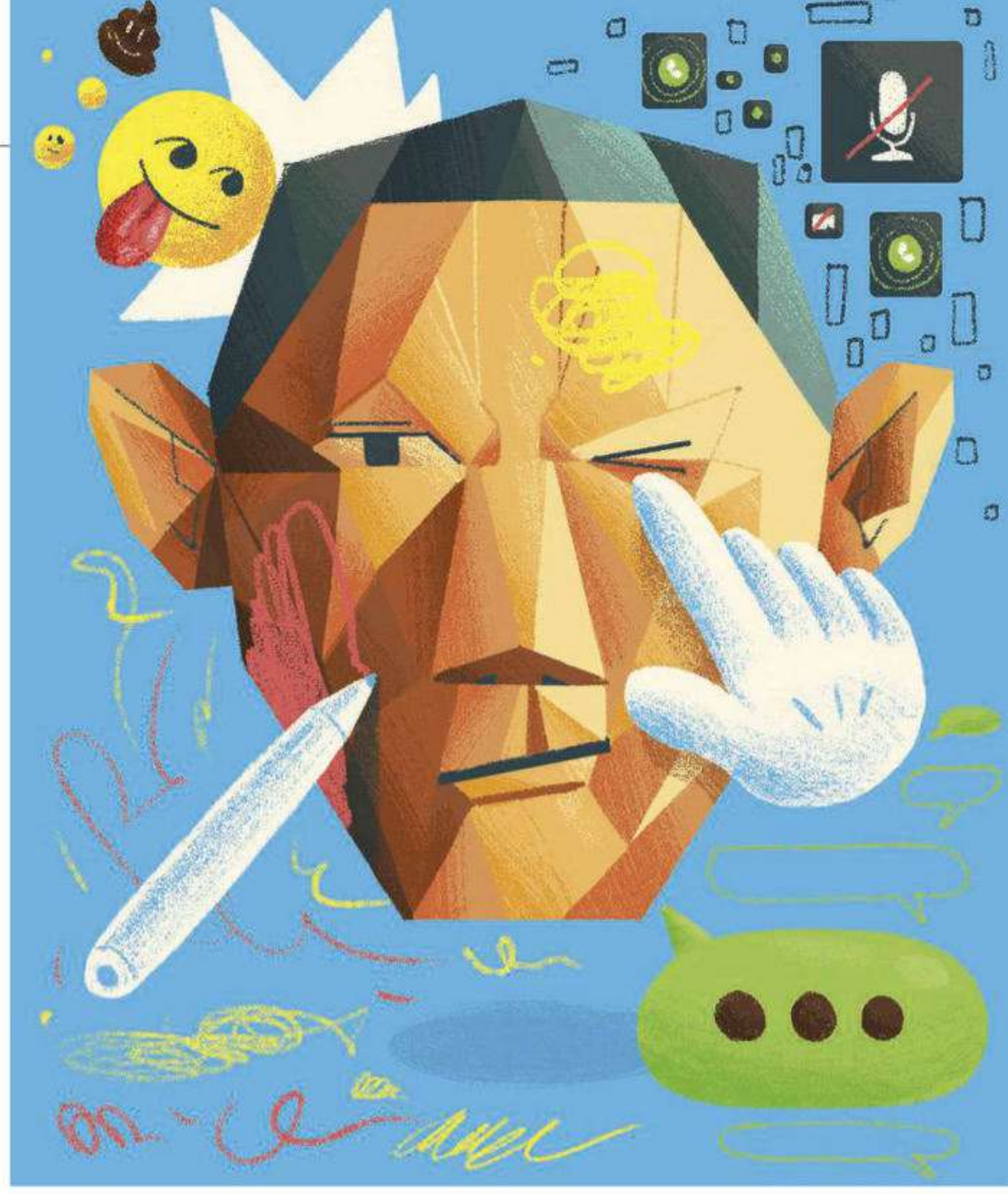
BBC TWO

PORTRAIT: KATE COPELAND ILLUSTRATION: JASON RAISH

COMMENT

NEW WORLD ORDER

In 1993, the internet was brought to the masses, changing the online world forever. Now, COVID-19 will transform our virtual lives again



September 1993 started out like every other September of the 25-year history of the internet: a new group of people arrived at university and were assigned an email address, giving them access to the online world. They started to nose around the world of information – archives upon archives of user-generated knowledge and labyrinths of non-physical communities – and got super excited. They dived in with both feet and invariably broke rules, pushed boundaries, and were put into place by an 'Elder' who'd explain how things actually worked in this virtual town. Usually by October, everything would be running smoothly again.

But 1993 was different. This was the year that AOL sent out CDs to every household in the USA, giving internet access to millions. This was the year that – for the first time – more people logged on than people who'd been there before. This was the beginning of what became known as the Eternal September, locked into online lore as the moment when everything changed. The Elders were replaced by newbies, rules were bulldozed and the old ways didn't matter any more. It was the original disruption in the new technology. And the internet that most people now know was born.

We are in the midst of another disruption, one ushered in by COVID-19. The people who lived through the Eternal September, and the newbies who created the culture of the tech that most of us recognise as dysfunctional yet necessary, are being overrun by the people who dabbled with social media, but didn't live it, businesses who thought working remotely meant checking your email while on holiday, and the people who thought virtual life ended when a person stopped living.

"People want a water cooler moment. They want in-person adoration"

What is notable about living through this moment, as a person who was part of the rush online in September 1993, is seeing how the remote worker, virtual mourner and social media butterfly are discovering the limits of this new normal. The digital services that we became dependent on because they were already there are not able to deliver the dream they promised. People want a water cooler moment. They want in-person adoration. They want to gather at a grave and physically hold each other.

As incredible as it is, today's digital tech doesn't replace human interaction. Yet that is what we've asked it to do for months. While it is possible for some people to entirely live a life online, that's not the case for everyone. Yet that's what we have all been asked to do.

What I find exciting is that people who would never have felt the discomfort of pushing against tech's human/digital boundaries, are beginning to recognise its limitations. And that will lead to innovation. Less than five years after the Eternal September turned the old internet on its head, we had new systems of search (Google), commerce (Amazon) and social networking (Six Degrees). The seeds for the dysfunctional internet we lived in pre-COVID were sown by newbies. The Eternal April will bring disruptions that the rest of us can't imagine, and newbies will invent a new world order of their own that will be greater than anything ever invented before. SF

ALEKS KROTOSKI

Aleks is a social psychologist, broadcaster and journalist. She presents *The Digital Human*.

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THE STRESS TEST

WORDS **AMY FLEMING**

WHAT IF MEASURING YOUR WELLBEING WAS AS SIMPLE AS TAKING YOUR TEMPERATURE? SCIENTISTS ARE TESTING OUT HEART RATE VARIABILITY, TO SEE WHAT IT CAN TELL US ABOUT OUR MENTAL HEALTH…

Before COVID-19, loneliness was considered a national epidemic, and as bad for you as smoking 15 cigarettes a day. But by the middle of June this year, social isolation had become the 'new normal' for more of us, with 7.4 million British people having experienced 'lockdown loneliness', according to the Office for National Statistics. The knock-on effects that stress and loneliness could be having on our physical health are potentially vast, although they can be hard to spot when we're in the thick of challenging times. A panic attack is relatively easy to identify, but the slow and steady creep of rising blood pressure or inflammation is less obvious.

Step forward, a little-known health marker called heart rate variability (HRV). HRV is a measure of the degree of variation in time between heartbeats. Greater variation means we're in a good place – resilient, in control of our emotions and ready for anything. Lower variation implies we need to prioritise self-care. This stress barometer of sorts can offer a window into the extent to which our mental health is manifesting in our bodies, and help motivate us to minimise our stress levels. HRV monitoring is increasingly offered through wearable devices, and understanding why it is relevant reveals some fascinating pathways between mind and body.

Let's go back and think about loneliness again. We consider loneliness to be a feeling, rather

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than a disease, but as social animals, the safety we sense when we are among friends and loved ones is crucial in regulating the body's autonomic nervous system (ANS). In turn, the ANS regulates involuntary bodily functions such as breathing, heart rate, blood pressure and digestion. Chronic stress and loneliness can cause an imbalance in the ANS, leading us to spend too much time in so-called fight-or-flight mode – something we hear an awful lot about in high-stress modern life. It can be life-saving in appropriate emergencies, but it is not a healthy state in which to linger. It puts a strain on the mind and body, so we spend too little time resting and recuperating, and HRV decreases.

HEALTHY BODY, HEALTHY MIND

Zooming in on our mind/body connection a little closer, information on what we sense and how we feel emotionally is constantly processed in a primitive region of our brains called the hypothalamus, which sends signals to the rest of the body through the ANS to intensify or relax bodily functions as needed. Fight-or-flight mode is governed by a wing of the ANS called the sympathetic nervous system. When this is activated, our pupils dilate – all the better to see an approaching threat. Digestion slows, while blood glucose is boosted in preparation to fight or flee. The opposing wing of the ANS is the parasympathetic nervous system, which governs 'rest and digest' and 'feed and breed' activities such as salivation, urination and sexual arousal.

All of these reflexes are part of our homeostasis system, which keeps our bodies stable, and ready to respond to changing environments. At rest, we should sit near the middle of the spectrum of sympathetic and parasympathetic activation. This healthy balance means we are at our most resilient and able to cope with stressors and changing circumstances, and is reflected in our HRV. Or as Amelia Stanton, a clinical research fellow in psychology at Harvard Medical School, puts it: "HRV tells you how the body is regulating its responses to external changes."

Over the last five years, we've seen fitness enthusiasts and couch potatoes alike cheerfully gamify their health stats, counting steps or logging lap records on their fitness apps. HRV fits into this picture perfectly. If you learn how to pimp your HRV scores, then it could help you become more resilient. Part of that might be identifying what causes you emotional stress and finding practical ways around those issues, from avoidance to better planning to seeking support from loved ones. Apps such as *Elite HRV,* and the accompanying app for

ABOVE Increased loneliness can lead to an imbalance in the autonomic nervous system, causing us to spend too much time in fight-or-flight mode

"People tend to be numb to their own bodies, and this [HRV tracking] gets them back into their body. So however they're doing it, it's helpful"

the sleep- and activity-tracking ring, Oura, encourage users to add customised tags – anything from exercise, sleep and meditation, to alcohol consumption, dietary changes and work deadlines – to each day's HRV reading, in the hope that over time, patterns will start to emerge. Low HRV scores also serve as a warning to take things easy when your resilience is lower, whether it's due to stress, cyclical hormonal fluctuations, illness or jet lag.

ABOVE There are various apps that can be used with wearables to track heart rate variability over time

READY FOR USE?

Interpretations of the data used for HRV readings vary between practitioners and apps. HRV data is complex, which, coupled with a fair amount of debate over best practice and the efficacy of unregulated consumer products, is presumably why HRV has remained out of the public consciousness up to now.

Dr Stephen Porges, director of the Trauma Research Center in the Kinsey Institute at Indiana University, has been working with HRV and emotional resilience since the 1960s. He was initially against consumer products being offered for HRV tracking at home, but he now concedes that, while the data from consumer devices are far from a clinical standard, such products "are helpful to people because they get them aware of their own body". When we're dealing with trauma and behavioural disorders, "people tend to be numb to their own bodies, and this gets them back into their body. So however they're doing it, it's helpful, and it's doing no harm," he says.

When I speak with Dr Marek Malik, emeritus professor of cardiac electrophysiology at Imperial College London, who was on the committee that published the first international standards for measuring HRV in 1996, he is furious. "Some of these gadgets are inappropriate and useless," he ➤

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HOW I TRACKED MY HEART RATE VARIABILITY (HRV)

I started monitoring my HRV during lockdown in May. At first I used a Wahoo Tickr chest-strap heart monitor, moving on to a more convenient finger pulse reader called CorSense. For consistency, I take my morning HRV reading as soon as I wake up, which involves pairing one of these devices to an app on my phone called *Elite HRV* and sitting still for two minutes. Afterwards, I am encouraged to log exercise, sleep, mood, soreness, energy levels, plus anything else I think might be relevant.

For HRV geeks, the app is packed with mysterious sounding data such as 'RMSSD' and 'HF Peak'. I keep things simple, and only pay attention to my 'morning readiness' scores of 1 to 10, along with my HRV. This is presented with a bar showing my balance between sympathetic (fight or flight) nervous system activity and parasympathetic (rest and digest). If I'm in the green zone in the middle, I'm good.

A month in, I started using an Oura ring, too, which takes my HRV while I sleep. The readings are an average from my entire night's sleep, and are dramatically lower than my morning HRV scores, although they largely rise and fall over time in unison with my morning readings. The Oura app doesn't give as much befuddling detail and you don't have to fiddle about in the mornings.

During my time of tracking my HRV, a glass or two of wine didn't seem to have an effect. Nor did switching from my regular tea to coffee in the the morning. A bad night's sleep, on the other hand, was an HRV disaster, as were times of stress or overwhelm. In the days before my daughter's birthday outing, with work deadlines either side, no childcare and a house guest to accommodate, my HRV plummeted. A gradual decrease in weekly averages could be seen as lockdown blurred into the summer holidays, and my patience with the pandemic restrictions took a hit.

says. "You need to have a controlled electrocardiogram. And even gadgets that would be appropriate technically, simply are unsuitable if they are used in the wrong environment and in the wrong conditions." He points out that HRV is affected by so many things that it's only relevant if taken in expertly controlled conditions.

Dr Paul Lehrer, on the other hand, who recently retired from Rutgers University in New Jersey, has spent most of his career studying the use of breathing to increase HRV to treat everything from anxiety to chronic pain. He says that most devices are adequate for this work, apart from finger pulse detectors on smartphones.

So it seems that if you want to track your HRV you must be mindful that it isn't gospel – in the same way that 10,000 steps doesn't necessarily equate to a healthy lifestyle.

AND BREATHE...

The type of breathing that increases HRV is known as resonant breathing, coherent breathing, or HRV biofeedback. "There are various rhythms in heart rate that each correspond to one of the body's control systems," explains Lehrer. "And two of these are involved in HRV biofeedback. One of them is called respiratory sinus arrhythmia – a rhythm that goes along with breathing and is controlled by the vagus nerve, which is the major parasympathetic nerve." So if you're boosting that rhythm, "you're essentially stimulating the vagus nerve – the system that helps to relax you."

The other is called the baroreflex, which regulates blood pressure. "The baroreflex is controlled by the sympathetic nervous system," says Lehrer. "But it has connections in the brain that connect to the structures that generate and control emotion." So during resonant breathing, he says, "you're stimulating systems that control emotion, essentially."

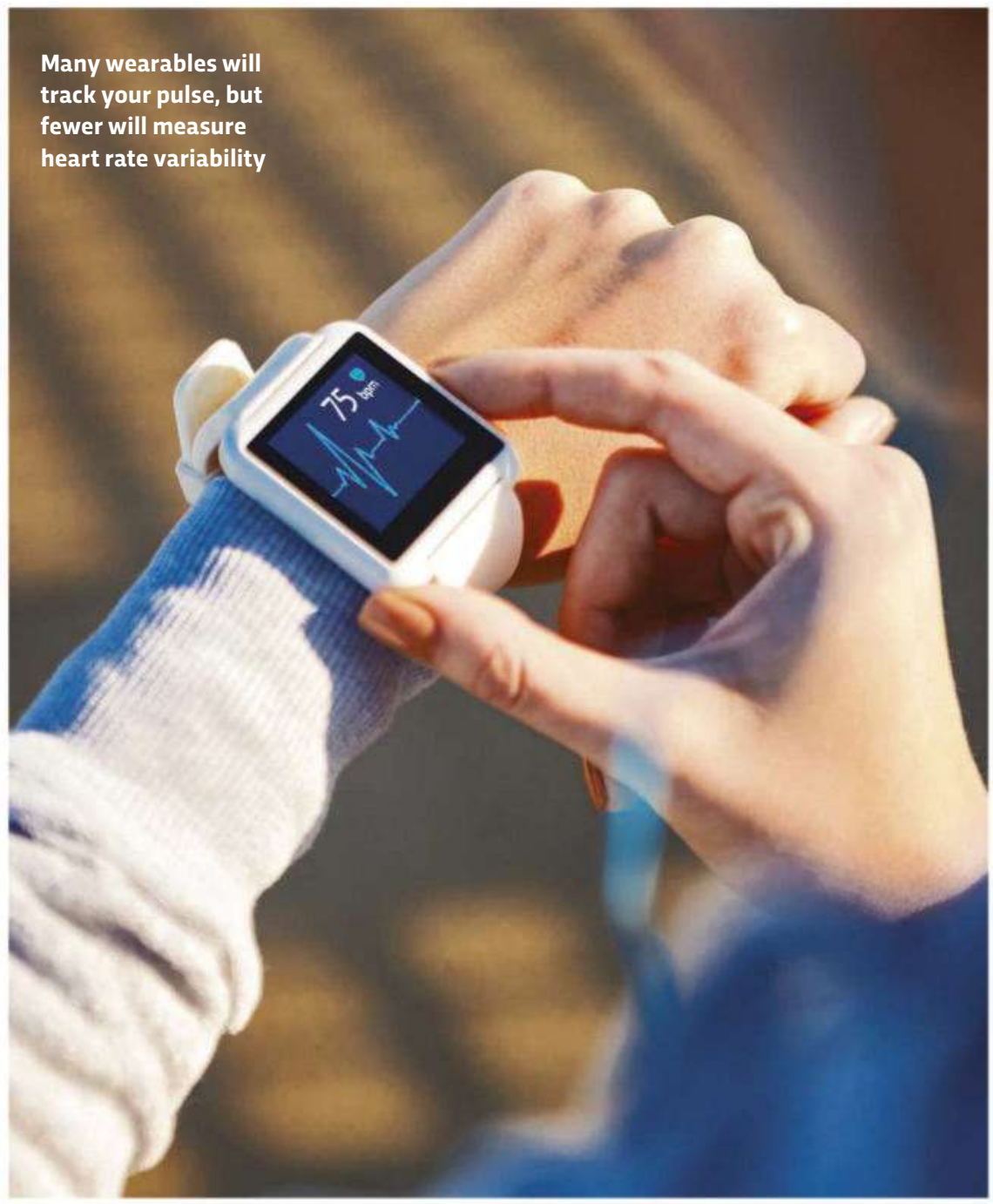
Resonant breathing is about synchronising those two heart rhythms. You slow your natural breathing rate of about 15 breaths per minute (respiratory sinus arrhythmia) to about six times a minute (baroreflex). To learn resonant breathing, you need a heart rate monitor connected to an HRV app, such as *Elite HRV* or *Coherence Trainer*, which shows increasing circles for inhaling and decreasing for exhaling and will let you know how well you're doing in real time.

"It's a godsend," says Porges. "It's a magic gift because we can access it through voluntary behaviour, and it has such profound effects on our neurophysiology." In fact he calls it a type of "neural exercise". Helpfully, in times of social distancing, we can do it on our own.

Slowing your breathing to any extent will have an effect, but it won't be as profound as with

HRV

The variation in milliseconds between your heartbeats is known as your heart rate variability (HRV). These minute differences in heart rate are normal – in fact , the more variation the better. This irregularity should not be confused with cardiac arrhythmia, which involves our heart rate, or pulse, which is measured in beats per minute. Cardiac arrhythmia is a serious condition that involves the heart beating too fast or too slowly, or throwing in extra, irregular beats.



Many wearables will track your pulse, but fewer will measure heart rate variability

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THE TELLTALE HEART – THE DIAGNOSTIC POSSIBILITIES OF HRV

HRV is not only a measure of emotional stability through its connection with the autonomic nervous system. It has potential as a valuable non-invasive diagnostic marker too. "If you have a patient in hospital who has survived the acute phase of a heart attack, before the patient is discharged, one could measure HRV over 24 hours using an electrocardiogram, and you would get an indication of whether the patient is at higher or lower risk," says Dr Marek Malik, emeritus professor of cardiac electrophysiology at Imperial College London.

Other diseases of the autonomic nervous system can be detected and monitored using HRV, such as autonomic neuropathy – damage to the nerves that control everyday functions. This can be caused by autoimmune diseases such as diabetes. "If I had a patient with diabetes, and I was concerned whether they already had some nerve damage due to the diabetes, I could investigate this using heart rate variability," explains Malik.

Using HRV for diagnosis is still largely at an experimental stage, but there are also indications, says Malik, "that it could be very useful in differentiation in patients of whether they need an automatic defibrillator implanted or not." These defibrillator devices can resuscitate some people after heart attacks, but not others, depending on their heart rhythm. However, he warns, these serious health diagnostics are only possible when carried out by doctors and experts with years of training and experience, who use specialist equipment. Consumer heart monitors and HRV apps are not suitable for medical use.

resonant breathing. This is because with resonant breathing, you are stimulating the blood-pressure control reflexes and the respiratory control reflexes that help control gas exchange, says Lehrer. As well as getting better athletic performance, exercise tolerance and oxygen control, you also get improved emotional control for people who are stressed or anxious.

Lehrer and his colleagues have shown that resonant breathing helps people who are suffering with emphysema, asthma, depression and related unexplained chronic pain. It is being used to treat PTSD in US veterans, and can even reduce cravings associated with various addictions. Lehrer usually recommends 20 minutes of resonant breathing twice a day, which he says will lead to "big changes in heart rate variability".

Elsewhere, Dr David Shearer, professor of elite performance psychology at the University of South Wales, used more accessible versions of HRV biofeedback, involving just five minutes of practice per day, and still got results. He uses HRV biofeedback as a tool for teaching emotional awareness and control, to help overcome those moments when athletes crumble under pressure, known as choking. "As sympathetic nervous system arousal increases under pressure, it reaches a point where it causes cognitive interference, to such an extent that it impedes performance," he says. "This can manifest itself in many ways, but might include high levels of anxiety, hyper-vigilance, poor decision making, and a lack of emotional awareness. Breathing at resonant frequency is a bit like hitting the reset button." He says that this effect can be replicated in everyday life. Who hasn't found themselves suddenly tongue-tied in an important meeting?

It's a skill that takes practice to master, though, and doing the breathing doesn't mean we should let other healthy choices slip. "The best training strategy treats the whole person," says Dr Fredric Shaffer, president-elect of the Association for Applied Psychophysiology and Biofeedback. "HRV biofeedback is only one piece of the puzzle." SF

"Resonant breathing, which boosts HRV, helps people who are suffering with emphysema, asthma, depression and related unexplained chronic pain"

by AMY FLEMING
(@Amy_Fleming)
Amy is a freelance science and health writer.

THE PSYCHOLOGY OF RESILIENCE AND HOW TO CULTIVATE IT

No matter what life throws at some people, they seem to roll with the punches and come through the other side stronger than ever. With many of us now experiencing bereavement, illness, job loss and insecurity, what can we learn from these resilient individuals and how can we be more like them?

WORDS **DR CHRISTIAN JARRETT**

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We hear a lot about the psychological toll that traumatic experiences can have on people. Flashbacks, nightmares, lives ruined. Yet there is something about the personality and mindset of others that means they can endure awful adversity, somehow come through relatively unscathed, and in some cases even emerge strengthened by it.

Joh Foster is one of these people. Even before being diagnosed with an aggressive form of breast cancer when she was 31, she'd already suffered a serious sexual assault, an abusive relationship, physical health challenges including a late diagnosis of Ehlers-Danlos syndrome, and various mental health issues. Yet she always bounces back. She somehow managed to complete her psychology degree while undergoing chemo and radiotherapy, and raising her son, who was aged four at the time. "Partly it makes me feel sad that I seem to unwittingly attract these kinds of experience," she says, "but in the main I choose to believe that I am a stronger, more resilient, open, empathetic person because of them."

Psychologists call this ability to walk through bad experiences 'resilience'. "It generally means adapting well in the face of chronic or acute adversity," says neuroscientist Dr Golnaz Tabibnia, who studies the neurological basis of resilience at the University of California, Irvine.

Understandably, research interest in why some people are more resilient than others is intensifying. The fallout from the ongoing coronavirus pandemic means that a huge number of people are confronted by various forms of adversity, including illness, bereavement, job loss, isolation and more, together with a constant sense of uncertainty over what the future holds. Is there anything we can learn from the study of resilience to help us cope with the difficult months and years ahead?

One way that psychologists have attempted to learn more about resilience is by studying groups of people who have all faced adversity and then looking to see what's different about the psychological makeup of those who seem relatively unaffected. Last year, for instance, a team led by clinical psychologist Dr Eric Meyer at the Department of Veterans Affairs in Waco, Texas, studied hundreds of American military veterans who'd served in wars in Iraq and Afghanistan. They found that those who exhibited lower-than-average signs of post-traumatic stress disorder (PTSD) – a mark of their resilience – tended to score highly on a trait known as 'psychological flexibility' (measured by disagreement with statements such as 'I am afraid of my feelings' and 'emotions cause problems in my life').

"Psychological flexibility gives us the ability to shift perspectives and actions when we're experiencing discomfort or difficulty without being overwhelmed," says psychologist and counsellor Dr Selda Koydemir, who teaches resilience to individuals and organisations (but wasn't involved in the veterans study). Another key aspect to psychological flexibility is not avoiding difficult

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"PSYCHOLOGICAL FLEXIBILITY GIVES US THE ABILITY TO SHIFT PERSPECTIVES"

emotions, but accepting them as part of life. "When we remain in contact with aversive experiences and approach challenging situations in an accepting and flexible way, we become more resilient and are more likely to pursue a meaningful life," Koydemir says. A final important part of the trait is prioritising what matters to you – your values and overarching goals in life – by focusing on what you can do, in spite of adversity, to reach those goals. "Psychologically flexible people show willingness to welcome uncomfortable states, if doing so helps them pursue their goals that are aligned with their values," adds Koydemir.

BE ADAPTABLE

Individual stories of fortitude chime with this idea that resilience emerges from an ability to adapt, combined with a strong motivation to pursue one's values. Foster agrees that it has helped her to find various coping strategies that work in different situations ("breathwork and tactile mindfulness are my go-tos for breaking the cycle of disruptive thought patterns") and she says that she has partly coped with adversity by channelling her energies and experiences into positives. "A couple of years after I was ill, I started volunteering for the breast cancer awareness charity, CoppaFeel!," she says. "I regularly go to schools, colleges, universities and workplaces, to talk about my experience and educate people on what to look and feel for. It has made a huge difference to me as it has essentially been the silver lining to the black cloud of cancer."

Psychologists studying resilience specifically in the context of the COVID-19 pandemic have also found psychological flexibility to be key. Dr Nima Golijani-Moghaddam and Dr David Dawson, clinical psychologists and researchers at the University of Lincoln, surveyed over 500 UK citizens in May 2020, as the country was in the midst of a nationwide lockdown, to find out how they were coping emotionally.

"The current pandemic confronts us with unfamiliar and changing demands, in a context of pervasive fear and uncertainty, and we wanted to explore the promise of psychological flexibility as a source of resilience under these conditions," says Golijani-Moghaddam. As you might expect, the pair found elevated levels of anxiety in their sample (27 per cent met the criteria for an anxiety disorder versus an expected 6 per cent during normal

THREE STRATEGIES TO BUILD YOUR RESILIENCE

AFFECT LABELLING
This is one of several psychological techniques you can use to help diminish the impact of negative emotions, which can make it easier to cope with unavoidable stress. It involves expressing in words, either in writing or out loud, the feelings that you're experiencing. An analysis published in 2018 of 42,000 tweets supported the effectiveness of this trick. It found that tweets containing a form of affect labelling, such as 'I feel sad', tended to be followed in the ensuing hours by tweets from the same person suggesting they were feeling calmer. Dr Golnaz Tabibnia, a neuroscientist at the University of California, Irvine, who studies resilience, adds that affect labelling doesn't just help in the moment, but can also help in the long-term. She conducted research with her team and found that repeatedly labelling the negative emotions conveyed by distressing images reduced the physiological arousal those same images triggered a week later.

BEST POSSIBLE SELF
This exercise can increase your positive emotions, which in turn can act as a buffer against future stress. "It consists of writing about and envisioning yourself in the future in detail, after everything has gone as well as it possibly could," says Dr Alba Carrillo, a health psychologist at Massachusetts General Hospital. "Afterwards, spend about five minutes visualising that image in your mind, closing your eyes and activating all your senses while picturing yourself in that future."

Carrillo was the lead author of a 2019 review that established the efficacy of the 'best possible self' (BPS) exercise based on the findings from 29 prior studies involving nearly 3,000 participants. "Precisely in these times, the BPS exercise can be a useful tool to help you to recover – or build – your excitement and hopes about your future," says Carillo. She adds that if it feels too frustrating to perform now, "you can try to imagine yourself some years from now when things are calmer".

VALUE-BASED APPROACH
Alongside managing your negative emotions and accentuating your positivity, you can practise accepting adversity and uncomfortable feelings in the spirit of living a value-based life. Grounded in acceptance and commitment therapy (ACT), this is about more just following your goals, explains Dr John Donahue, a clinical psychologist based at the University of Baltimore who practises and teaches ACT. "It refers to the quality of our intentions," he explains. "The coronavirus has reminded us how much our world can quickly change in ways that are beyond our control, though we do have control over our choices in the moment. Can those choices be driven by meaning and importance? In this way, connecting with our values during these times of uncertainty can provide direction when the path forward is foggy."

Donahue was co-author of a 2019 study that showed how value-based living helped university students remain resilient in the face of stressful life events.

"IT IS ALL ABOUT SHOWING UP TO WHAT IS HERE FOR US AT THE MOMENT, AND MOVING FORWARD DESPITE THE DISCOMFORT"

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times), but crucially, those individuals who scored higher for psychological flexibility were less likely to be experiencing anxiety or depression, and also reported higher overall wellbeing.

The good news for developing our own resilience for the months and years ahead is that most psychologists agree it is something that can be taught, at least partly. "We were particularly interested in psychological flexibility [in the context of COVID-19], because there is good evidence to suggest that this is something that we can change," says Golijani-Moghaddam.

HOW TO BE RESILIENT

If you want to cultivate your own resilience, or the resilience of those you care about or are responsible for, there are three elements you can focus on: developing a suite of coping mechanisms; nurturing the psychological flexibility to accept difficult emotions, and knowing how and when to deploy your various coping strategies; and finally, being mindful of your values, so that you can continue to live a meaningful life in the face of adversity.

In terms of coping mechanisms, there are psychological techniques to ameliorate the impact of negative emotions, such as 'affective labelling' (that is, naming your feelings) and cognitive reappraisal (thinking about things in a more constructive light, such as seeing lockdown as a chance to learn a new skill). These techniques are particularly useful for when stressors are unavoidable, says Tabibnia. Then there are other methods you can use to accentuate your positive emotions, such as deliberately dwelling on memories of good experiences from your past, and seeking ways to boost your optimism (such as by using the 'best possible self' exercise, see box, left). These positivity-building strategies can help buffer the effects of stress, Tabibnia says.

ABOVE Psychologist Dr Selda Koydemir says that we can build resilience by approaching challenging situations and difficult emotions in a non-judgmental, flexible way

On their own, however, these techniques are not enough – being psychologically flexible (and therefore resilient) is about knowing which techniques to use and when. Partly this comes through practice, which means being willing to confront difficult situations in life, rather than being overly avoidant.

"Often when we're faced with a stressful situation, our tendency is to freeze and completely avoid it," says Tabibnia. However, this rarely helps deal with the situation and it can even make matters worse, undermining our confidence and potentially allowing problems to escalate. In contrast, confronting sources of stress – including focusing on what is within your control – won't just help manage the situation, it will also prepare you better for the future. "Even taking action that ultimately doesn't change the stressor can change the brain's response to the stressor

"THE RESEARCH BEING CONDUCTED ON RESILIENCE DURING THIS PANDEMIC WILL HELP US GET THROUGH WHATEVER 2021, 2030 OR 2050 HAS IN STORE"

LEFT The fallout of the coronavirus pandemic has led to an increase in resilience research, to find out why some people appear to deal with adversity better than others

and reduce the experience of distress, suggesting that the mere feeling of having some control over the situation is helpful," Tabibnia explains.

In terms of accepting difficult emotions rather than always seeking to avoid them, Koydemir clarifies that this doesn't mean being passive or submissive. "It's a non-judgmental stance towards what is going on and involves recognising our options for action and moving towards where we want to go without our control. Ask yourself 'What am I able to do in this situation?' and direct your energy and effort toward the issues that you can influence."

Finally, a guiding principle that can secure your use of emotional regulation strategies and non-judgmental acceptance is

the notion of value-based living (see box, p74). "Know what matters to you in life and behave in ways that will take you to them," says Koydemir. "Ask yourself 'Is what I'm doing working or helpful?'" These approaches to psychological flexibility and being more resilient are part of acceptance and commitment therapy, which is an offshoot from cognitive behavioural therapy (CBT). "It is all about showing up to what is here for us at the moment, and moving forward despite the discomfort," Koydemir adds.

As we all adjust to the uncertainty that lies ahead, we can perhaps take heart from tentative, real-world evidence that suggests resilience really can be taught. Dr Adam Vanhove, an organisational psychologist at James Madison University, recently worked with his colleagues to survey the findings from 37 prior studies into workplace resilience training programmes. They found a modest benefit to the programmes, which might not sound fantastic, but bear in mind that most of the programmes had yet to be grounded in a mature evidence base. Also, the larger benefits were enjoyed by those who arguably needed them most. "People in high-stress jobs or who have a history of not demonstrating resilience can gain [coping] tools and learn how to use those tools from resilience training," says Vanhove.

Vanhove adds that a silver lining to come out of the pandemic is that it has prompted a torrent of new psychological research into resilience. We already know a lot about the formula for bouncing back from adversity, but in just a few years we can expect to know much more. "The research being conducted on resilience during this pandemic will help us get through whatever 2021, 2030 or 2050 has in store in a way that no other event in the recent past has," he says. **SF**

by **DR CHRISTIAN JARRETT** *(@Psych_Writer) Christian is a psychologist, and senior editor at* Psyche *magazine. His next book,*Personology, Using The Science Of Personality Change To Be Calmer, Confident And More Fulfilled *will be out in May 2021.*

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Q&A

YOUR QUESTIONS ANSWERED

... DO LIONS PURR?
... HOW MANY TREES DO I NEED TO PLANT TO CARBON OFFSET MY LIFE?
... WHY DO WE NEED SLEEP AND WHY DID IT EVOLVE?
... WHY ARE FOUR-LEAF CLOVERS SO RARE?
... HOW CAN I SEE THE ANDROMEDA GALAXY?
... WHO IS CHARLES DREW?
... WHAT DOES 'STATISTICALLY SIGNIFICANT' MEAN?
... HOW DO SEA TURTLES REMEMBER WHAT BEACH THEY WERE BORN ON?
... DO 3D PRINTERS WORK IN SPACE?

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OUR EXPERTS

PROF MIKE BERNERS-LEE
Expert on carbon footprints

DR CHRISTIAN JARRETT
Neuroscientist, psychology expert

DR PETER J BENTLEY
Computer scientist, author

JAMES LLOYD
BBC Science Focus staff writer, with a meteorology PhD

ALEX FRANKLIN-CHEUNG
Environment and climate expert

DR HELEN PILCHER
Biologist, science writer

PROF ALICE GREGORY
Psychologist, sleep expert

LUIS VILLAZON
Science and technology writer

ABIGAIL BEALL
Science and space writer

DR HELEN SCALES
Marine biologist, science writer

DR NISH MANEK
Medical expert, GP trainee

PROF ROBERT MATTHEWS
Physicist, science writer

ILLUSTRATION: DANIEL BRIGHT

ADAM KING, HUDDERSFIELD

WHICH OF OUR SENSES EVOLVED FIRST?

We have lots of different senses, including a sense of balance, heat, pain, and the ability to sense the position of our limbs (called 'proprioception'). But if we consider the five classic senses, then taste is the oldest by a wide margin. Taste is really just the ability to detect particular chemicals in your immediate environment, and ocean-dwelling bacteria were sensing nearby nutrients and swimming towards them at least two billion years ago. Sight, or at least the ability to detect light, was another bacterial invention, but true image-forming eyes didn't evolve until multicellular animals appeared around 570 million years ago. By then, many single-celled organisms had also evolved the ability to sense touch. Smell normally means the ability to detect chemicals carried in the air, so this sense had to wait around another 70 million years for the first land animals to emerge.

Hearing in air came last, because sound waves are weak compared to electromagnetic waves such as light, and require specialised structures to amplify the signal, especially for high frequencies. Fully-functioning ears didn't evolve until 275 million years ago. But in 2015, Danish researchers suggested that lungfish may have had a rudimentary sense of hearing. These fish were probably the earliest vertebrates to start making forays onto land, around 375 million years ago, using their fins to 'walk' from one shallow pond to another. The study suggests that they could detect low-frequency sounds in the air via vibrations of their head, giving them an early forerunner of what eventually evolved in land animals to become the middle ear and eardrum. ***LV***

DEAR DOCTOR...

DELICATE ISSUES DEALT WITH BY *SCIENCE FOCUS* EXPERTS

WHY DO I FEEL ANGSTY AND CABIN FEVER-Y IF I'M INSIDE FOR MORE THAN A FEW HOURS?

'Cabin fever' isn't a formal psychological term, but it describes the feelings of restlessness and irritability that many of us experience when stuck indoors, especially during the recent lockdown months. This angsty frustration is quite understandable, as confinement can thwart what many psychologists consider to be our three basic psychological needs: 'autonomy' (choosing what we do), 'competence' (feeling like we're achieving our aims, for example by mastering skills and situations, which is tricky when you can't go out), and 'relatedness' (feeling connected to others). Potentially compounding matters is the loss of opportunity for physical exercise, fresh air and sunlight, which are all good for our bodily and psychological wellbeing. If you're stuck on your own, loneliness is another obvious risk; on the other hand, excessive time in close quarters with housemates, partners, siblings or parents can lead to rising tensions.

Thankfully, these sources of angst also point to ways to reduce it. Try to structure each day so that you have some feelings of control, consider using the time as a chance to learn new skills, and be sure to stay in touch with absent friends and family via phone or video call. Also, exercise regularly if you can, and respect the privacy and space of those you live with. Finally, if you have the luxury of a garden or balcony, don't forget to get some fresh air. ***CJ***

KAMILA MAGOMEDOVA (AGED 13)

DO LIONS PURR?

Lions can make gurgling noises that sound purr-like, but opinion is divided as to whether these are true purrs. True purrs, as practised by domestic cats, occur on both the 'in' and 'out' breath, and are produced when a solid bone at the back of the throat – the hyoid – resonates. Lion gurgles, in contrast, are made only on exhalation, and the animals have a flexible hyoid bone that prevents them from purring properly. Purr-dantic? Maybe, but it's a big deal if you're a big cat! ***HP***

MICHAEL STAND, NEWCASTLE-UPON-TYNE

WHAT DOES 'STATISTICALLY SIGNIFICANT' MEAN?

Scientists often claim discoveries are based on results that are said to be 'statistically significant'. This is widely taken – even by scientists – to imply that the effect they've found is real; for example, that the cut in death rate produced by a new drug isn't just a fluke. In fact, it merely means that the chance of getting so big an effect by fluke is less than 1 in 20. Statisticians have repeatedly warned that this is not the same as the chances that the effect really was a fluke. Working that out requires an assessment of the plausibility of the result, which is rarely ever done. As such, despite its widespread use, statistical significance is an unreliable measure of whether an effect is genuine. ***RM***

GETTY IMAGES, ALAMY ILLUSTRATIONS: DANIEL BRIGHT

HIDDEN FIGURES

CHARLES DREW
CREATED THE FIRST LARGE-SCALE BLOOD BANK

Blood banks are a vital part of any health service, giving doctors rapid access to this life-giving fluid. But blood is notoriously hard to store. Left to itself, it clots and loses vital components like platelets. It is also delicate. Red blood cells rupture if badly handled, and any contamination can make it potentially lethal.

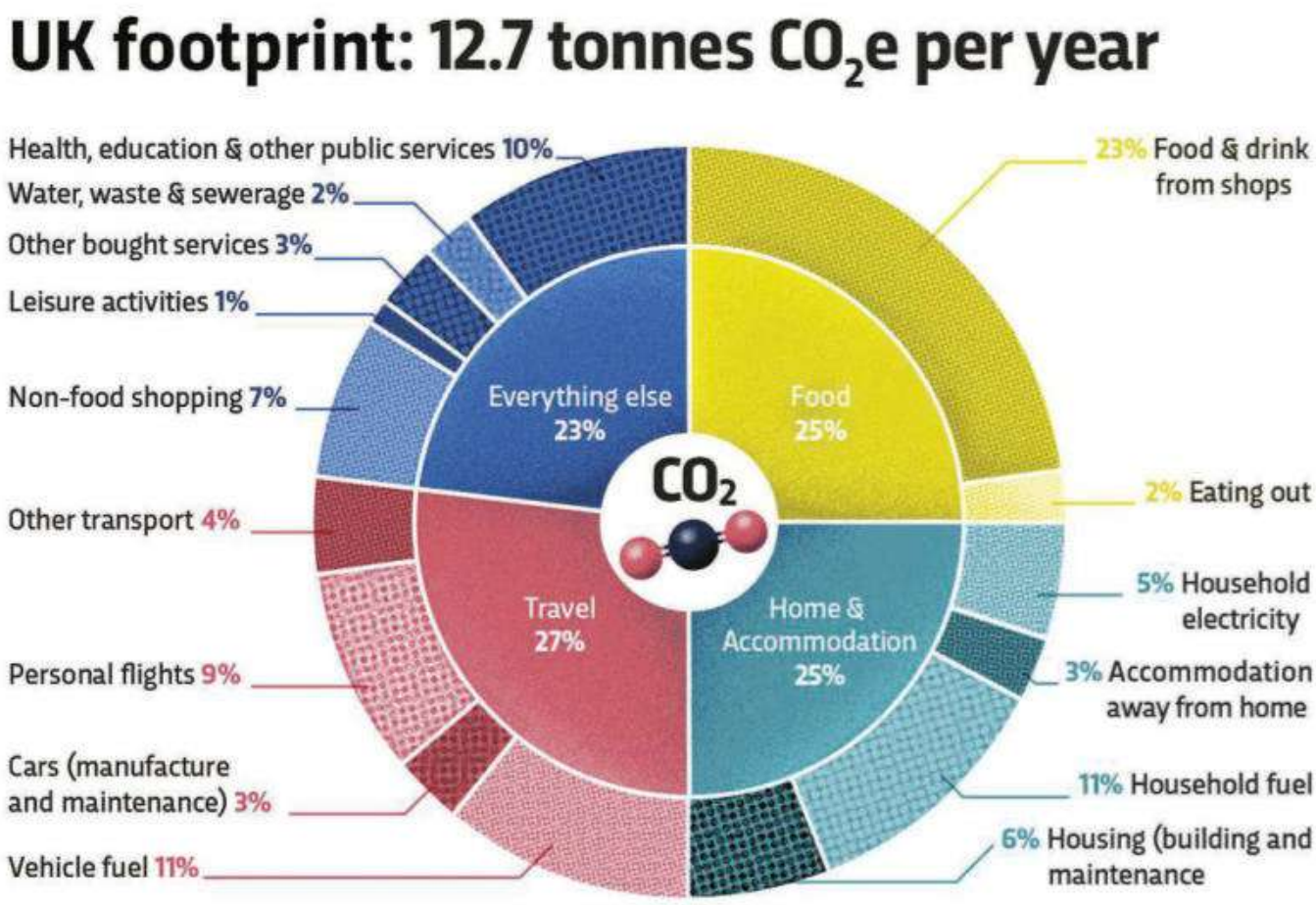
In 1940, these were the challenges facing Dr Charles Drew, a brilliant 36-year-old African-American surgeon based in New York. Having just finished a doctorate on blood preservation, Drew had been asked to help get blood supplies to wartime Britain.

He quickly focused on plasma, the liquid component of blood, which could keep longer without refrigeration than blood cells, and be given to anyone, regardless of blood group. Drew pioneered a blood bank network which separated plasma from donated blood using spinning machines called centrifuges, and then treated it with an antibacterial agent and ultraviolet light. Within months, the blood banks were shipping thousands of litres of plasma to Britain, saving the lives of thousands of soldiers and civilians.

The following year, Drew began creating a blood bank network for the American Red Cross. But when officials insisted blood from white and African-American donors be segregated, Drew resigned. He returned to work in surgery until his tragic death in a car accident, aged just 45. *RM*

ANDREW CIREL, CHIPPENHAM

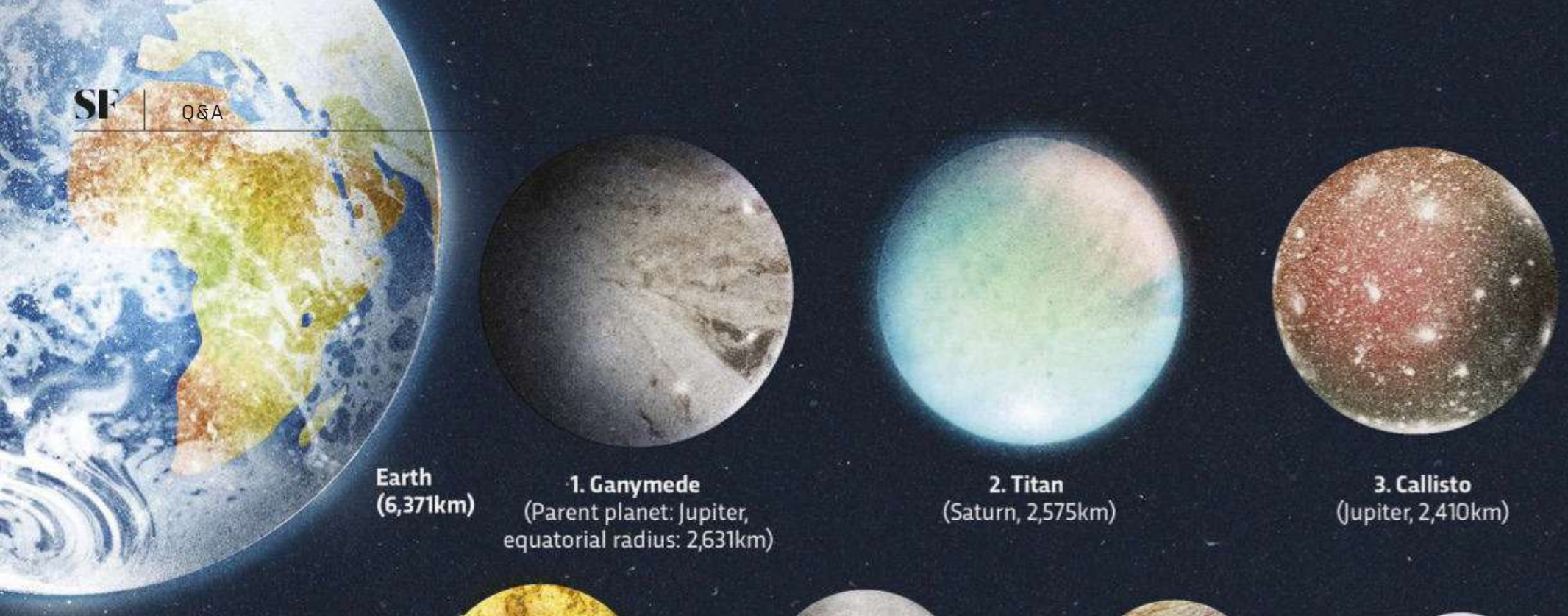
I'M 47. HOW MANY TREES WOULD I NEED TO PLANT TO CARBON OFFSET MY LIFE?



Data taken from the new edition of *How Bad Are Bananas? The Carbon Footprint Of Everything* by Mike Berners-Lee (£10, Profile Books)

The average person in the UK has a carbon footprint of about 13 tonnes per year. This is a 'carbon dioxide equivalent' value (CO_2e), as it also includes emissions of other greenhouse gases such as methane and nitrous oxide, adjusted so that the warming from these gases can be compared to the warming from carbon dioxide. Multiplying that figure by 47 years, and taking into account the fact that average carbon footprints have generally increased since you were born, gives a rough value of 500 tonnes CO_2e (assuming also that your carbon footprint as a child was equal to that of an adult).

This value of 500 tonnes is about the same amount of CO_2 that would be taken out of the atmosphere if you planted a hectare (100 x 100m) of mixed broadleaved woodland in the UK and let it grow for 50 years. This would be about 2,250 trees, and it'd cost you between about £10,000 and £25,000 to do this through a government grant-aided scheme. However, there are only so many trees we can ever plant in the UK, or even in the world. And it takes years for trees to capture useful amounts of carbon. So tree-planting projects have their limits. Much better is to reduce our carbon footprint in the first place by addressing some of the segments in the pie chart above. ***MBL***



DAVID GRIFFIN, GLOUCESTERSHIRE

WHY DO NEWS REPORTS ALWAYS BEGIN WITH BAD NEWS?

CORONAVIRUS
BBC NEWS
Coronavirus: UK deaths
More than 30,000 people have died with suspected Covid-19
• Johns Hopkins University: Virus deaths exceed 250,000 globally
11:04

Most news outlets lead with disasters, crimes and misdemeanours. This is partly down to media convention – there's the old media adage "if it bleeds it leads", and many journalistic reputations are forged through the uncovering of establishment scandals or ineptitudes (true to the notion of the media as the 'fourth estate' that helps keep those in power in check). Of course, negative stories are also important in the practical sense of informing us about dangers, such as global pandemics or an incoming inclement weather.

Yet there is another side to this question: the overwhelming reader demand for gloom and doom. This is likely explained by what psychologists have long recognised as our 'negativity bias' – we pay more attention to, and better remember negative experiences. We're more likely to spot angry faces than happy ones in a crowd, and many languages have a much wider vocabulary for describing negative emotions than jolly ones. This bias probably evolved as a survival mechanism, and it affects our taste in news. In one 2014 study, researchers in the US and Canada tracked volunteers' eye movements as they browsed an online news site, and found that even those who professed a preference for positive stories actually spent more time scanning the negative ones. Another study led by the University of Michigan showed that across 17 countries, from New Zealand to China, people on average showed stronger emotional reactions (measured by skin conductance and heart rate variability) to negative news stories. But this wasn't true for everyone, so the researchers say that there could be a niche market for positive news, too. ***CJ***

GETTY IMAGES, ALAMY, NASA ILLUSTRATION: DANIEL BRIGHT

Barry 'Butch' Wilmore showing off the 3D-printed ratchet wrench that was made on the ISS

CHRIS MAYHEW

DO 3D PRINTERS WORK IN SPACE?

Yes! NASA's 'In-Space Manufacturing' project has been running since 2014, when the first 3D printer was sent to the International Space Station. The printer releases a stream of heated toothpaste-like plastic from a tube and deposits it layer by layer to create a 3D object, and it was found to work perfectly in microgravity. Objects created by this printer and its successor include a ratchet wrench, an antenna component and a part to connect two onboard robots. ***PB***

CROWDSCIENCE

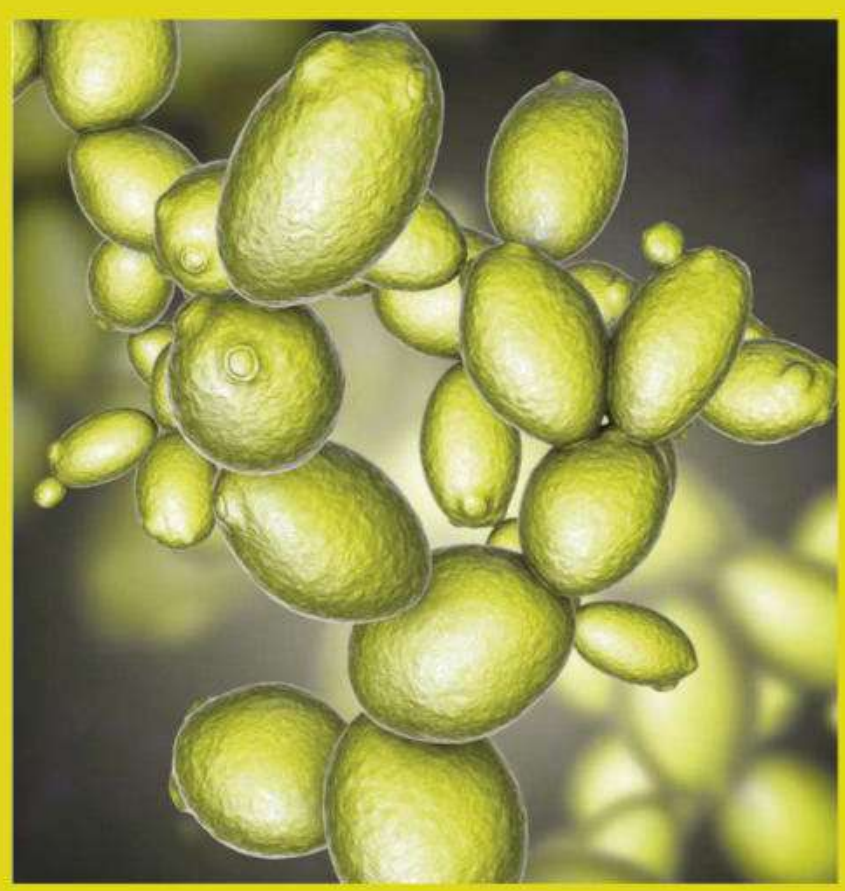
Every week on BBC World Service, *CrowdScience* answers listeners' questions on life, Earth and the Universe. Tune in every Friday evening on BBC World Service, or catch up online at **bbcworldservice.com/crowdscience**

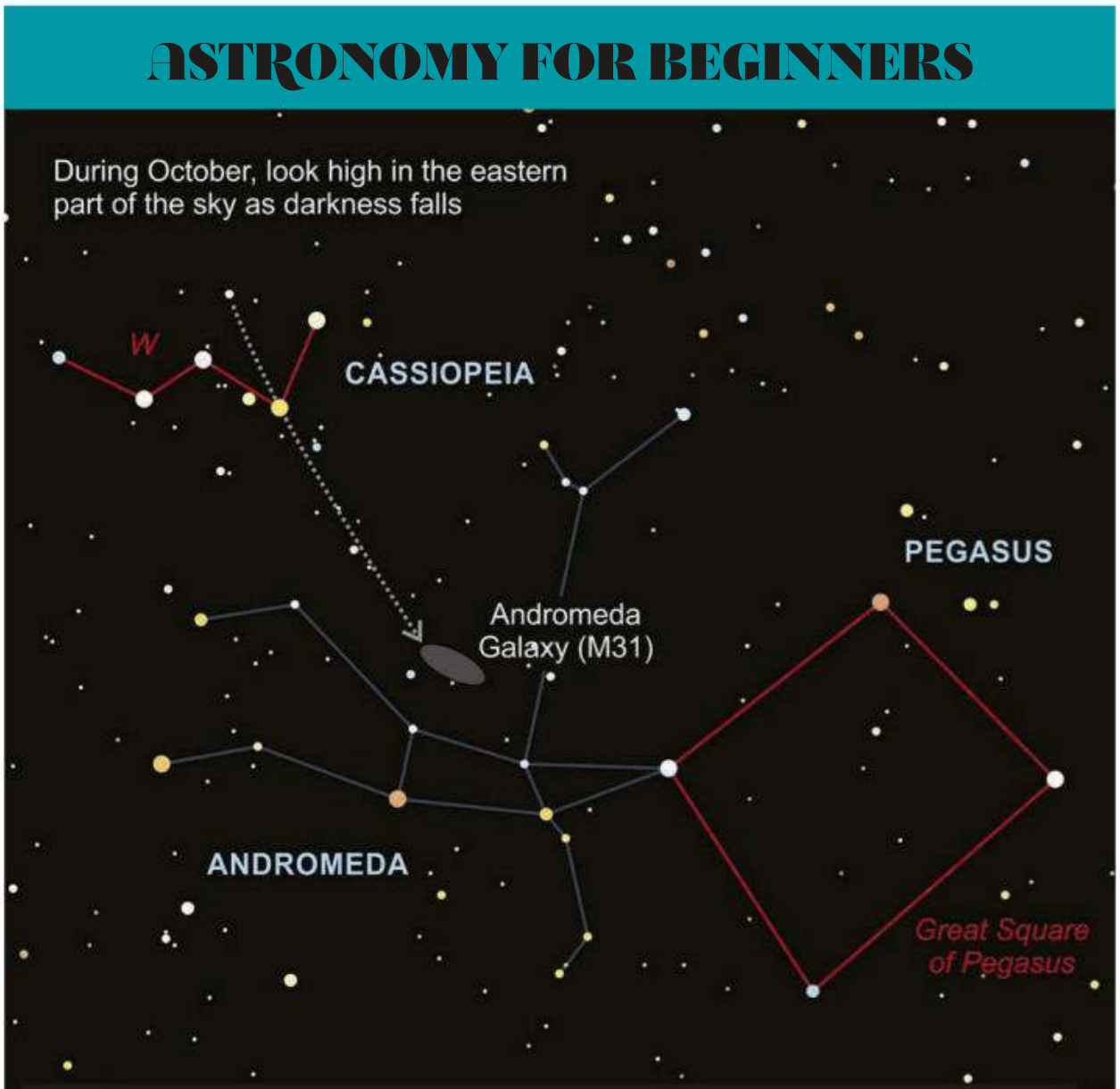
WHAT IS THE YEAST DOING INSIDE MY BREAD?

Yeast is a single-celled microbe belonging to the fungus family. There are around 1,500 known species, but the one used in baking is *Saccharomyces cerevisiae*. Its key property is the production of carbon dioxide (CO_2) when it feeds on sugar molecules (a process known as fermentation). The CO_2 gets trapped, creating a soft, spongy texture.

There are billions of yeast cells in a single sachet of yeast. The sugar they feed on comes from the bread's flour, which is mainly starch: long chains of glucose molecules. These chains are too large for the yeast to metabolise, but bread flour also contains 'amylase' enzymes (these occur naturally, but are also often added to flours to boost levels), which, when you add water, chemically chop the starch chains into individual glucose molecules. The yeast cells eat this glucose, which they convert into energy, releasing water and the all-important CO_2 as a by-product.

Yeast grows and multiplies fastest between 30°C and 35°C, which is why your dough rises best in the airing cupboard or on a warm windowsill. Towards the end of the proving, the yeast starts to run out of oxygen, so it can't fully metabolise the sugar. Instead, it switches to an anaerobic process that doesn't need oxygen, and produces alcohol (ethanol) instead of water as the by-product. You can often smell the slightly fruity/sour products of this process in raw bread dough. When you bake your loaf, the heat of the oven evaporates all the alcohol, and also kills off the yeast cells, which have now done their job. ***LV***





HOW CAN I SEE THE ANDROMEDA GALAXY?

WHEN: VISIBLE ALL YEAR, BUT CLEAREST DURING THE DARK WINTER MONTHS

At 2.5 million light-years from Earth, the Andromeda Galaxy is the most distant object visible with the naked eye. It's the closest major galaxy to the Milky Way, and can only be seen if you have a really dark sky. However, the good news is that it's visible all year round from the UK.

To find Andromeda, it's easiest to start with the constellation Cassiopeia. For northern hemisphere stargazers, Cassiopeia is what's known as a 'circumpolar' constellation, which means that it's always visible above the horizon. Look towards the northeast and you'll recognise Cassiopeia by the distinctive 'W' star pattern (or 'asterism') that its five brightest stars make.

Once you've found Cassiopeia, you can use the right-hand half of the 'W' as an arrow pointing towards Andromeda. The distance between Cassiopeia and Andromeda is about three times the height of the W. With the naked eye, Andromeda will be extremely faint. But if you have a pair of binoculars, look through them and you'll see what looks like a cloud. That's an entire galaxy.

While you're in this part of the sky, you can also use the nearby 'Great Square of Pegasus' asterism to test the light population in your area. The Great Square is visible in the UK between August and December, and during October it can be seen all night. It has four bright stars arranged in an almost perfect square shape, and you'll find it below and to the right of Cassiopeia's 'W'.

Once you find the Great Square, let your eyes adjust and then count the number of stars you can see inside it. If you see no stars, it means the light pollution in your area is poor. The average number of stars is 4, 9 stars is good and 21 is excellent. The most you'll ever see with the naked eye, in the darkest skies, is 35. *AB*

AKRIVI FARMAKI, LONDON

WHY DOES ONLY ONE NOSTRIL GET BLOCKED WHEN YOU'RE SICK?

It's down to what's known as the 'nasal cycle'. We might not realise it, but our bodies deliberately direct the airflow more through one nostril than the other, switching between nostrils every few hours. A constant airflow can dry out the nostrils, which damages their lining, so giving one nostril a rest helps prevent this from happening.

When we have a cold, the blood vessels in the nose dilate as part of the body's immune response, and the nose also produces more mucus. Both of these changes cause congestion, but you'll feel more blocked in the nostril that's currently 'off duty'. The nostril with the full airflow might feel fine. ***NM***

3,236

The number of satellites Amazon plans to launch into orbit to provide global internet coverage. This will more than double the current number of 2,666 active satellites!

AMOS ASHLEY

WHY ARE FOUR-LEAF CLOVERS SO RARE?

As in animals, plant genes are located on tiny packages of DNA in the nucleus of every cell, called chromosomes. Whereas human chromosomes come in matched pairs, clovers have *four* copies of each chromosome per cell. The gene responsible for four-leaf clovers is 'recessive', which means that the plant will only produce four leaves if it has the four-leaf gene on all four chromosomes, which is a rare occurrence. Even then, environmental conditions such as temperature and soil acidity will also have an impact on whether the four leaves develop. A 2017 survey concluded that around 1 in 5,000 clovers is four-leaved, but they do tend to be found in clusters. ***LV***

BERTIE WEST

WHERE IS THE RAINIEST PLACE ON EARTH?

Where is the rainiest place on Earth? Surprisingly, it's not Wales. According to Guinness World Records, the place with the highest average annual rainfall is the village of Mawsynram in northeastern India, which receives nearly 12,000mm of rain per year (Cardiff, in comparison, receives just 1,150mm.) Mawsynram is situated high up in India's Khasi Hills and is directly in the path of warm, moist air swept in from the Bay of Bengal. Most of Mawsynram's rain falls during its monsoon season, which lasts from around April to October every year. ***JL***

QUESTION OF THE MONTH

SEDA PIREFENDI

HOW DO SEA TURTLES REMEMBER WHAT BEACH THEY WERE BORN ON?

Hatchling sea turtles emerge from their nests, scramble down the beach and swim off into the open sea, where they feed and grow. Many years and thousands of miles later, mature turtles return to their birthplace, to mate and produce their own offspring. It's an incredible navigational endeavour, which has probably evolved to give hatchlings the best chance of survival (if a turtle successfully hatched on a beach, then there's a good chance the beach will still be a suitable nesting site when it comes back).

To pull off this feat, turtles call on a range of senses. Swimming through open seas, there's evidence that turtles can navigate using the position of the Sun. Smells are also important. In aquarium tests, juvenile loggerhead sea turtles responded to the smell of mud piped into the air, by swimming with their heads out of the water, but they ignored other odours, suggesting they recognise the characteristic scent of land.

Probably the turtles' most important, and certainly most mysterious, sense is magnetoreception – their ability to detect the Earth's magnetic field. It's unknown exactly how they do it, but turtle hatchlings follow an inbuilt magnetic compass during their first swims offshore. Turtles also home in on slight variations in magnetic fields. Around Florida, for example, loggerhead turtles learn the magnetic signature of their natal beach.

Green sea turtles tracked with satellite tags in the Indian Ocean were recently shown to follow a fairly crude magnetic map. Often they overshot their destination island by hundreds of miles, but were able to reset their route or search until they found their target, perhaps using a combination of senses. ***HS***

WINNER

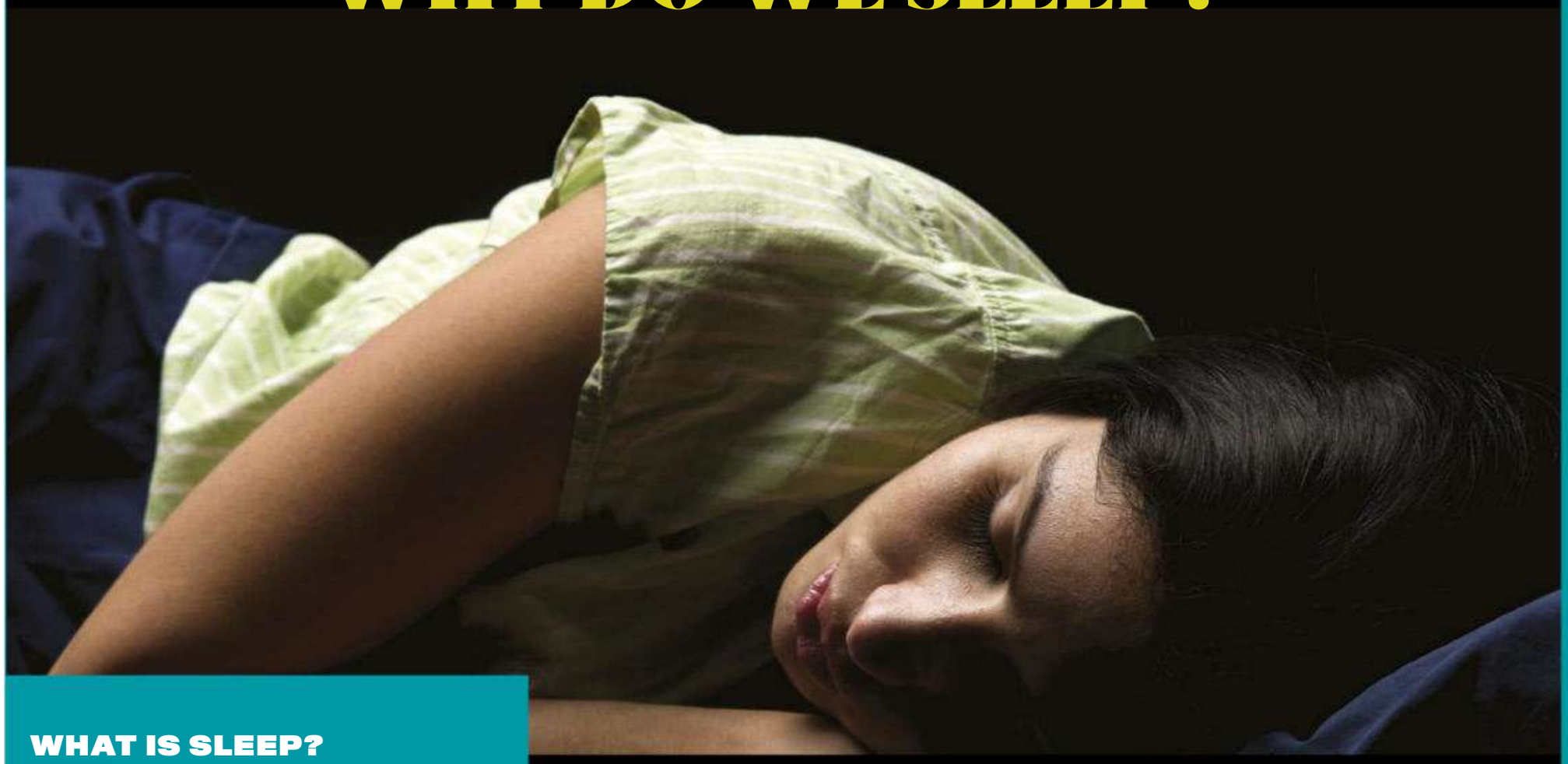
Seda wins a pair of **Outlier Gold earbuds**, worth £94.99. These stylish earphones have 14 hours of playtime per charge, or 39 hours when coupled with the case. They are compatible with Apple Siri and Google Assistant, boast Super X-Fi audio, and are sweatproof too. **uk.creative.com**

EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM** OR TWEET US **@SCIENCEFOCUSQA**

GETTY IMAGES X2, ALAMY ILLUSTRATION: DANIEL BRIGHT

THE EXPLAINER

WHY DO WE SLEEP?



WHAT IS SLEEP?

Sleep is a state of altered consciousness in which we become less aware of what's going on around us. Sleep can take different forms in different animals. Dolphins, for example, sleep just half a brain at a time, and can even continue to swim while asleep.

For humans, sleep involves four stages, called N1, N2, N3 and rapid eye movement (REM). N1 is the lightest stage of sleep. It usually occurs right after you fall asleep, and typically lasts less than 10 minutes. During N2, you sink deeper into sleep. This stage is characterised by brief, high-amplitude brainwaves called 'K-complexes' and bursts of lower-amplitude waves called 'sleep spindles'. The N3 stage is the deepest stage of sleep, and is characterised by slow brain waves called delta waves. Finally, during REM sleep your brain activity and breathing rate speed up, and your eyes move quickly in lots of directions. Our most vivid dreams tend to occur in REM sleep, and our brain paralyses our muscles so that we're unable to act them out. During the night, we continually cycle through these four sleep stages, with a full cycle taking around 90 minutes in adults.

HOW MUCH SLEEP DO WE ACTUALLY NEED?

It depends how old you are! A 2014 review of the scientific research concluded that toddlers (aged one to two) typically need between 11 and 14 hours of sleep per night, and this then decreases with age. Teenagers typically need around 8 to 10 hours of sleep, while adults need around 7 to 9 hours a night. There are differences between us, though, and some adults can function perfectly well on six hours of sleep. However, you're probably kidding yourself if you think you can get by on four hours! It is also possible to sleep too much: adults are not recommended to have 11 or more hours of sleep a night. There are links between excessive sleep and medical problems including cardiovascular disease, obesity and diabetes, but it's not clear why this is. It might be that these conditions cause oversleeping in the first place, or that sleeping when our bodies would more naturally be awake can harm the body in some way.

SCIENCE PHOTO LIBRARY, GETTY IMAGES X4

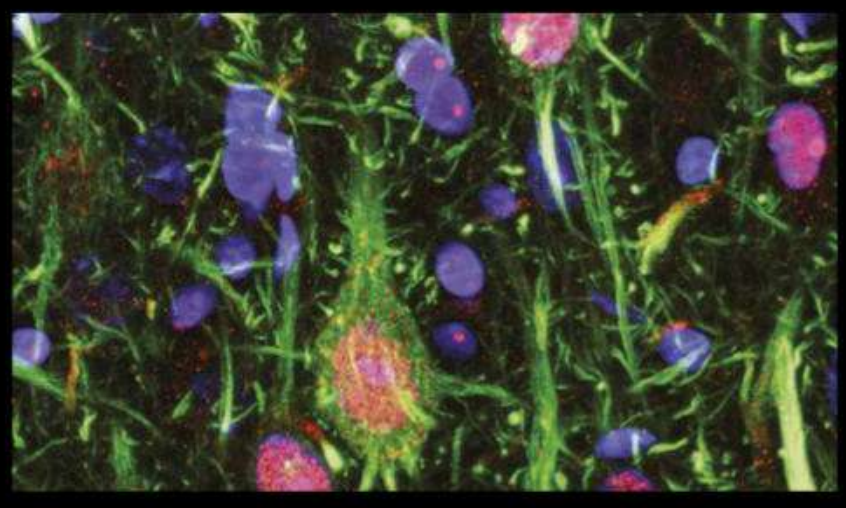
WHY DID SLEEP EVOLVE IN THE FIRST PLACE?

The evolution of sleep is something of a paradox. We spend around 30 per cent of our lives sleeping, but during this time our vigilance is at its lowest and we're less likely to notice threats. Sleep would have made our ancient ancestors less aware of, say, a prowling tiger. We're also typically unable to eat, drink or reproduce while we sleep – all of which are key for our survival. The eminent sleep scientist Allan Rechtschaffen said, "if sleep doesn't serve some vital function, it is the biggest mistake evolution ever made." Evolutionary theories include the idea that sleep allows us to conserve energy and save it for when we're awake, or that sleep actually makes us *less* vulnerable to threats during the darkness of night by keeping us immobile and less likely to wander into danger.

WHY DO WE DREAM?

The psychoanalyst Sigmund Freud suggested that dreams provide clues about the 'unconscious mind', arguing that they give us a way to fulfil hidden desires. Many scientists now reject this theory, because his ideas were based on only a small number of people, and it's also difficult, if not impossible, to test some of his ideas. A more popular idea is that dreaming helps us to process and deal with the emotions that we've experienced during the day. Another theory is that dreaming provides a kind of 'virtual reality' model of the world, enabling us to test out certain cognitive processes. Our dreams may also provide a kind of survival mechanism by allowing us to simulate potential threats or rehearse social situations in advance. Finally, it might be that dreams serve no specific function, but are simply the by-product of our brain's ceaseless activity while we sleep.

WHY DO OUR BODIES NEED SLEEP?



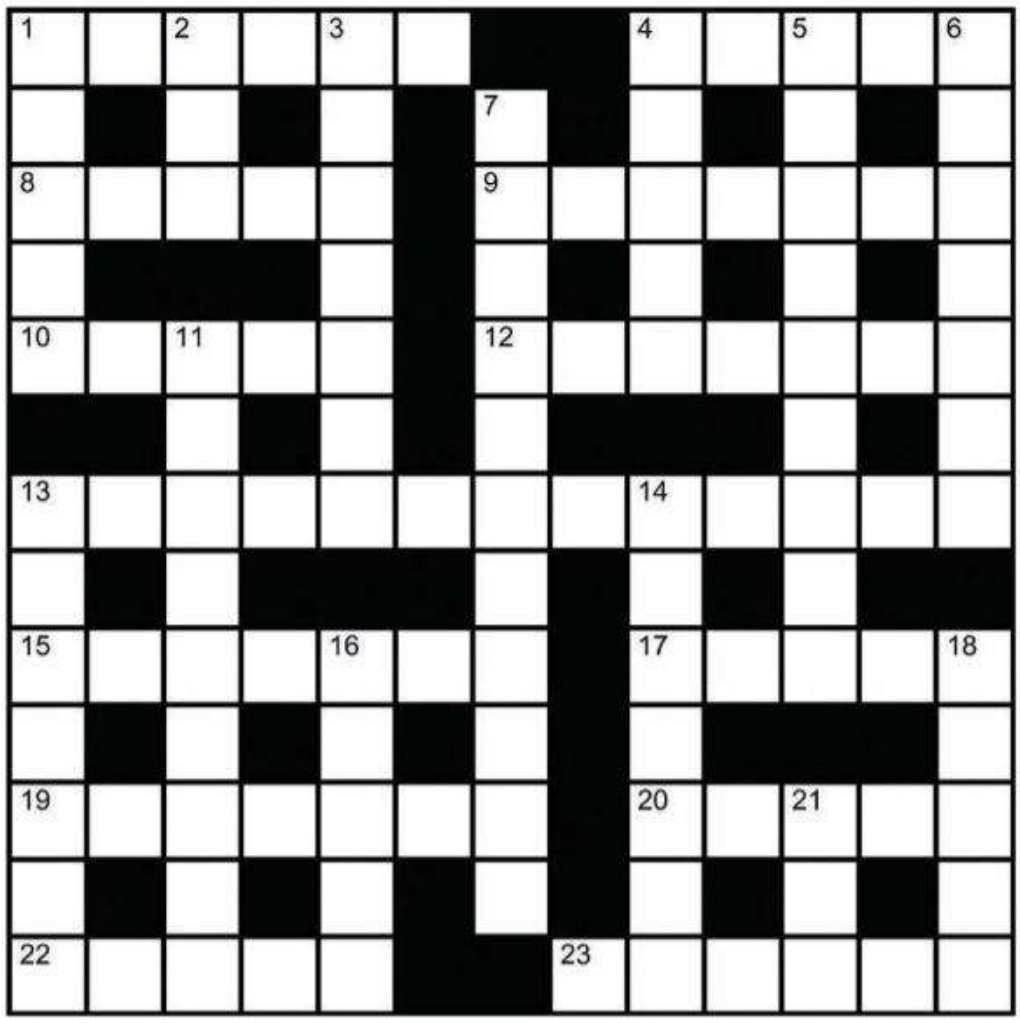
Sleep has multiple benefits for our bodies and brains – a fact which also helps to explain why sleep evolved. For example, sleep is important for the production of certain hormones, such as the growth hormone, which, among other things, stimulates the regeneration of damaged and dying cells. Sleep also allows us to restore, retune and finely balance certain physiological processes within our bodies. An example of this is the 2013 finding by researchers at the University of Rochester, New York, that the toxins which build up in our brains during waking hours are flushed out of the brain during sleep. Sleep also plays an important role in boosting our immune system, in learning and consolidating memories and in emotional regulation – essentially, our ability to manage and control our feelings and behaviour.

by **PROF ALICE GREGORY**

Alice is a sleep scientist at Goldsmiths, University of London, and author of Nodding Off *(£16.99, Bloomsbury Sigma).*

CROSSWORD

GIVE YOUR BRAIN A WORKOUT



ACROSS

1 Robbery and rip-off by a city's borders (6)
4 Building material prisoner left somewhere in the Med (5)
8 Scandinavian food (5)
9 Country changes are in another (7)
10 Live like a headless chauvinist (5)
12 Boy conceals desire to be a doctor (7)
13 Performing in calm cabaret with two humps (8,5)
15 Paid no attention to soldier returning with negative socialist (7)
17 Old nuisance, starting sauce (5)
19 The first opponent has one, but it's inconsequential (7)
20 Search for a tiny amount (5)
22 Foe has Yemen mobilised (5)
23 Musical agreement (6)

DOWN

1 Fake jewellery is finished, to a point (5)
2 About to have nothing but eggs (3)
3 Inventor of smashed rare cot (7)
4 Trouble by registered minder (5)
5 Dim peer is worried about a bit of skin (9)
6 Learnt about pursuing energy that's everlasting (7)
7 Attractive European girl shows its figures get smaller each time (7,4)
11 At home with money, I have to find motivation (9)
13 Get angry, just a whisker (7)
14 Limit fellow to a spindle (7)
16 Wet air around city (5)
18 Canoe unsuitable for so much water (5)
21 Animal in glasses (3)

ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

GETTY IMAGES

NEXT ISSUE

IT'S A SLUG'S GAME

You might think of slugs as being grey, slimy and... well... a bit boring. Maybe their flashier underwater cousins will help to change your mind.

PLUS

THE PROBLEM WITH ALGORITHMS

Why do algorithms go wrong?

ASTRONOMY FOR BEGINNERS

Peer into the skies and try to spot the Pleiades star cluster.

ON SALE 29 OCT

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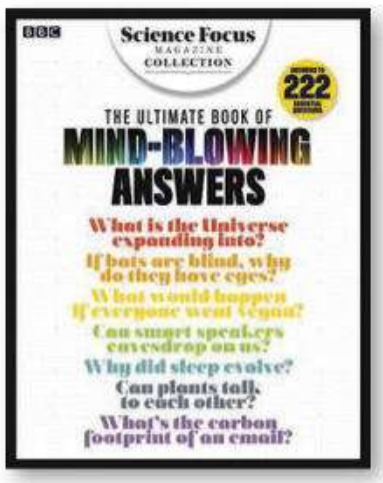
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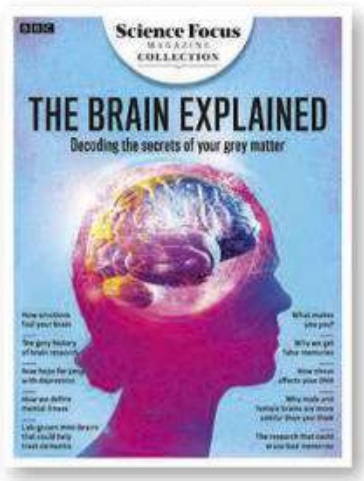
ANSWERS
What is the Universe expanding into?
If bats are blind, why do they have eyes?
What would happen if everyone went vegan?
Can smart speakers eavesdrop on us?
Why did sleep evolve?
Can plants talk to each other?
What's the carbon footprint of an email?

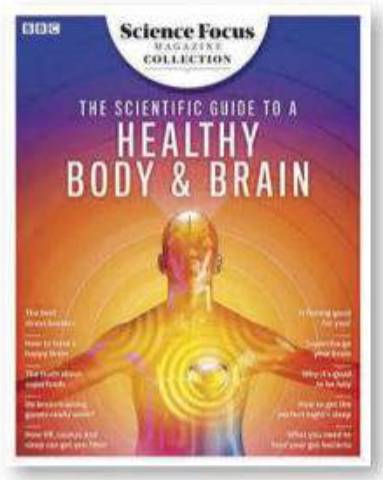
Truth is often stranger than fiction, as the 222 mind-blowing answers to what seem like simple questions demonstrate in this Special Edition.

Be astounded by incredible insights from the cutting edge of science, and meet the radical researchers who are stretching our knowledge to the limit.

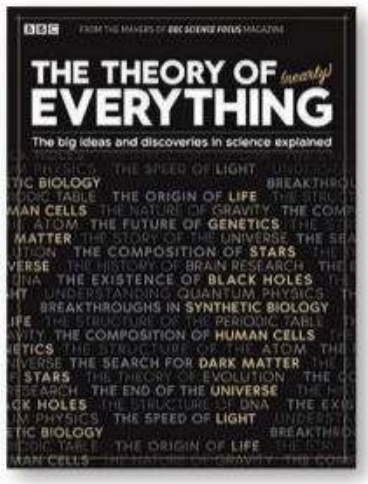


Find out about the extraordinary abilities of the brain, the evolution of intelligence and the latest research into mental health.

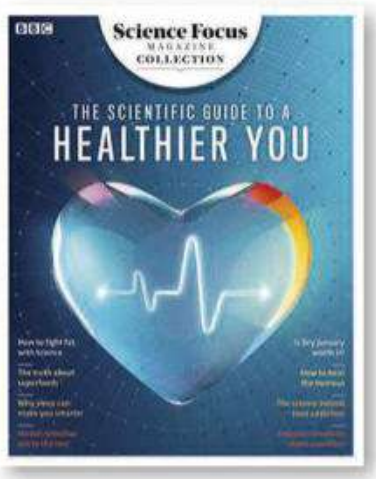
Discover more about the missions that will help unravel the mysteries of the cosmos as they venture everywhere from our closest neighbours to the galaxies far, far, away.



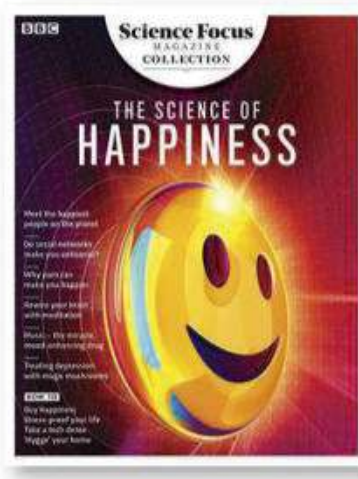
Allow science to show you the best ways to keep your brain sharp and your waistline slim, while staying fit, healthy and happy.



This special issue explains the fundamental concepts of science, and reveals the latest cutting-edge research that will change our world.



Experts reveal the science behind what really works when it comes to losing weight, eating right, keeping fit and sleeping well.



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A SCIENTIST'S GUIDE TO LIFE

HOW TO MAKE THE PERFECT CUPPA

IN BRITAIN, WE DRINK AROUND 165 MILLION CUPS OF TEA A DAY, SO LET'S GET IT RIGHT. FOOD SCIENTIST **DR STUART FARRIMOND** REVEALS ALL...

MAKE IT IN A MUG...

… or a tea cup. Avoid disposable Styrofoam cups. They're the worst. Styrofoam is porous so it will absorb some of the flavour compounds and affect the taste. If you're on the go, opt for reusable cups made from inert materials like ceramic or glass. Plastics can absorb flavours over time, so will kill the flavour of what you're drinking.

IF YOU LIKE YOUR TEA SWEET, GO FOR AN ORANGE MUG.

There's a huge amount of psychology involved in the way we perceive taste. For example, hot drinks taste sweeter if they're in an orange or red mug, compared to if they're in a blue or white mug. Similarly, if you were to drink from a fine bone china cup, you'd probably associate that with being special, and would be more likely to taste and appreciate the flavours.

LOOSE LEAF GIVES MORE FLAVOUR THAN TEA BAGS.

This is because the leaves have more space to move around and distribute their flavour. That said, well over 90 per cent of the tea drunk in this country comes from tea bags. Historically, this would have been of poorer quality because tea makers used to keep their best leaves for loose leaf tea. That's not true now, and tea makers go to great lengths to ensure the quality of their tea bags.

WATER QUALITY IS IMPORTANT.

Most of your tea is water, after all. If the water is too soft and doesn't contain any minerals, the tea can taste soapy. If it's too hard and contains a lot of minerals, such as calcium and magnesium ions, it can cause scum to form on the tea's surface. This looks unsightly and can alter the flavour. If you live in an area with hard water, you can soften the water by filtering it.

LET IT BREW.

Most people let their tea brew for around two minutes, but five minutes is ideal. It's too hot to drink before then anyway, and the extra time means your tea will have more flavour and antioxidants. Warning – if you leave the bag in for too long, you'll also end up with more tannin molecules, which can make the tea taste bitter. When we did research as part of BBC Two's *Inside The Factory* programme (look out for it on iPlayer), we found that the antioxidant levels were 13.9mg with a 30-second brew, but were more than double that after a five-minute brew.

MILK OR HOT TEA FIRST?

If you're making tea in a mug, add the milk after the tea, at the last possible moment before drinking, so the tea stays as hot as possible for as long as possible. Make sure you use freshly boiled water. All this will help the flavours to diffuse through the liquid.

NON-DAIRY MILK IS GOOD.

Although you can't call it 'milk' – it's basically nut juice! I'm doing some research on this at the moment, but the take-home message is that oat milk tends to have a good flavour profile for mixing with teas and coffees. SF

DR STUART FARRIMOND

Stuart is a tutor in food science at Cambridge University, a science writer and broadcaster. His latest book is The Science Of Spice *(£20, DK).*

Interviewed by Dr Helen Pilcher.

NEED TO KNOW...

1

If you use reusable cups, opt for ones made from ceramic or glass.

2

Let your tea brew for a little longer to get the best flavour profile and an antioxidant hit.

3

Oat milk is a good dairy alternative to add to your tea and coffee.

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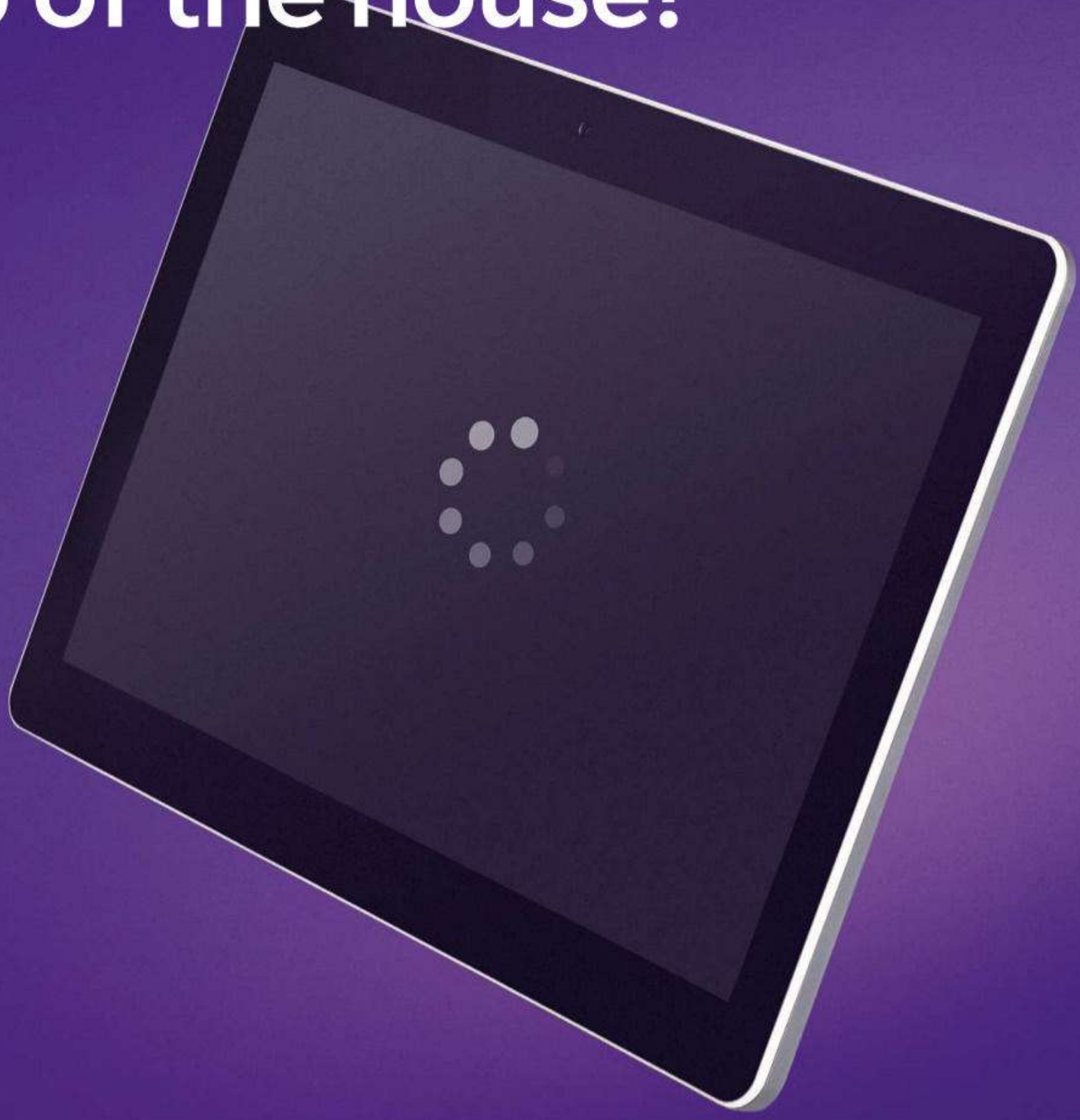

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